DEPARTMENT OF THE INTERIOR

REPORT

OF THE

CHIEF ASTRONOMER

FOR THE

YEAR ENDING MARCH 31

1908

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REPORT OF THE CHIEF ASTRONOMER AND INTERNATIONAL BOUNDARY COMMISSIONER.

DEPARTMENT OF THE INTERIOR,
DOMINION ASTRONOMICAL OBSERVATORY,
OTTAWA, CANADA, June 24, 1908.

W. W. CORY, Esq.,
Deputy Minister of the Interior,
Ottawa.

SIR,—I have the honour to report as follows upon the work of the Astronomical Branch of the Department of the Interior, and on the surveys under my direction, namely, the International Boundary Surveys and the Geodetic Survey of Canada, for the fiscal year ending March 31, 1908.

The correspondence of the branch from April 1, 1907 to March 31, 1908, was:—

Letters received (exclusive of circulars)	1,864
Letters sent	3,135
	4,999

Showing an increase of 26 per cent.

Accounts dealt with, 848.

Increase, 14 per cent.

A statement of the work of the photographic division is appended. (Appendix No. 5).

The library contains 3,144 bound volumes, besides pamphlets, unbound periodicals, &c., and is increasing rapidly from the addition of scientific journals, exchanges with other observatories, &c. An upper flooring has been placed in the library room, with a number of steel bookcases, almost doubling the accommodation.

A small room in the basement has been fitted out for the purpose of a chemical laboratory. This is a great convenience for many purposes, especially in connection with the astrophysical work.

The meridian circle, objective 6 inches aperture, and 7 feet focal length, with circles 36 inches diameter, was received from the makers, Messrs. Troughton & Simms in October, and was erected in the western wing of the observatory. Unfortunately it was found on examination that both the circles were bent, doubtless through rough handling in shipment of the case containing them. They consequently had to be sent back to the makers and they have not yet been returned here. Without the circles, the instrument could have been used as a transit instrument merely, but certain improvements and alterations were found necessary to the building, which have so far prevented its use. In the meantime, all the time work of the observatory is done, as hitherto, with a portable transit instrument in the temporary transit shed to the east of the main building.

Collimators have been placed north and south of the meridian circle, in its building; it is intended to place meridian marks outside, at as great a distance as practicable, both north and south.

The building of the coelostat house was begun last fall, but not completed before frost. The work has been resumed this spring and it is expected that the building,

with the apparatus, will soon be in use. This house stands behind the main building, with which it is connected by a tunnel. Through this tunnel the sun's rays will be reflected by the mirrors into a room in the basement where a grating spectroscope and other instruments for investigation of the radiation will be installed.

The workshop has proved its utility both in economy and convenience. A large amount of repair work has been done both to observatory instruments and to those used on the surveys. Besides this a registering micrometer has been made for one of the portable astronomical transits. A polarizing photometer for use on the large equatorial has been made, as well as several attachments to the spectrograph. It has been found necessary to appoint an assistant to the mechanician, as there was too much work for one man to attend to.

A building to contain the comparators of linear measures used on the surveys is in course of erection on the observatory grounds. Provision will be made in this building for apparatus for the comparison of tapes and other measures up to 50 metres in length.

The practice of opening the observatory to the public on Saturday evenings has been continued. A member of the staff is always present on these occasions to exhibit the large telescope, and to explain the various celestial objects observed. Appreciation of this is shown by the large attendance, when the night is fine.

Much interest is also manifested in the lectures of the Royal Astronomical Society of Canada, which are given every two weeks from October to May in the observatory lecture room. While the want of easy means of communication from the city no doubt keeps many away, there have been occasions when our room has been taxed to its utmost capacity. The astronomical and other scientific work of the observatory comprises the following:—

1. Geophysical work. This is under the direction of Dr. Klotz; it comprises seismological observation and investigation, and observations for the values of the magnetic elements at outside points. Gravity observations also come under this heading, but, for various reasons, nothing in this line has been done during the year. Daily records of the seismograph have been kept.

An invitation from the International Seismological Association, extended through its president, to Canada to join the association, was accepted by Order in Council of July 10, 1907. The association has for object co-operation between scientific workers over the world in the study of the earthquakes and earth movements, with a view to the ascertainment, so far as possible, of the conditions of occurrence of earthquakes, and of the internal constitution of the earth. Dr. Klotz was present at the meeting of the association, at the Hague, last September.

The magnetic observations, which have been taken at many stations, covering a wide range of longitude westward from the Atlantic coast, also are of scientific interest in connection with the investigation of the structure of the earth, as well as having practical value to those who use the magnetic compass. For details of the work done the reader is referred to the report of Dr. Klotz, in Appendix No. 1, to this report.

2. Astrophysical, and allied work. This is under the direction of Mr. Plaskett, and is described in his report in Appendix No. 2.

The observations comprise measurements of the velocities in the line of sight of binary stellar systems, other spectrographic work, solar photographs, photometric and micrometric star measurements, observations of occultations of stars by the moon, and miscellaneous phenomena. Special attention has been paid to the first mentioned, the measurement of radial velocities and the reduction of the observations with their application to the determination of the forms of the orbits. As there are not a great many observatories engaged in this kind of work, the subject being indeed a comparatively new one, it has been thought that systematic investigation in this line, for which our instruments with the improvements and adaptations devised by Mr. Plaskett are well suited, was a proper contribution of Canada to science.

3. Meridian observation and time service. This is under the direction of Mr. R. M. Stewart. (See Appendix 3.) As the meridian circle has not yet been installed, observations under this heading taken in the observatory have been confined to transit observations having for purpose to determine the time regularly for the service of the observatory and the time system in the city, and to serve the purpose of the time exchange when the longitude of distant points is being determined.

The time service to the government buildings has been satisfactory. It has been extended to the city post office, which has several dials and a large illuminated tower clock, all operated by a synchronized clock of the usual pattern in the basement. From this circuit is also operated a public clock which has been erected by the Ottawa Electric Company in front of their office on Sparks street. Dials have also been placed in the Printing Bureau, the Archives Building and the Royal Mint, but, owing to delay in the preparation of a room for the governing clock and its apparatus, these dials have not yet been put in operation.

In Mr. Stewart's report will be found a description of some improvements in mechanism which have been made under his direction in connection with the synchronized clock, and in the recording transit micrometers, as well as an account of an investigation which he has made of the errors of observations with the portable transit, in which he has had in view the securing of greater accuracy in the astronomical field work.

4. The determination of latitudes and longitudes, for geographical purposes, has been continued as usual. Five stations in Yukon Territory, Dawson, Selkirk, Tantalus, Whitehorse and White-Pass, have been determined in latitude and longitude. The longitude of Dawson was first determined by exchange of signals with the station on the 141st Meridian, which was occupied for longitude in 1906 for international purposes; the other longitudes were then determined by exchange with Dawson. The observers were Messrs. F. A. McDiarmid and W. C. Jaques.

The following stations in Eastern Canada were also determined:—Pembroke, Mattawa, Labelle, Roberval, Lake Edward, Rivière à Pierre, Barry Bay, Scotia Junction and Chapleau. The observers were Messrs. McDiarmid, Jaques and French. The longitudes were determined by direct exchange of time with the observatory. Mr. Stewart taking the observations here.

The operations of the Geodetic Survey, under the direction of Mr. C. A. Bigger, comprised extension of the reconnaissance, preparation of the stations for observing by two signal building parties, observing the angles, and precision levelling by two parties along railway lines in the southern part of the province of Quebec. The scheme of triangulation, as far as to this date developed by the reconnaissance, is shown on a map accompanying this report. The preparation of the stations over this area is well advanced.

Only one observer could be put in the field to measure the angles of the triangles, since we had but one instrument of sufficient size and power to secure the required accuracy. This was a twelve-inch theodolite, made by Messrs. Troughton & Simms. Two more twelve-inch theodolites have been procured, and the measurements will progress more rapidly hereafter.

The area actually covered by the angle measurements last year was about 3,500 square miles, situated between the Ottawa and St. Lawrence rivers. A high degree of accuracy was obtained, the average of the closing errors of the triangles being less than one second.

A base line several miles in length has been laid out near Coteau Junction, with a well conditioned expansion to the triangle sides, but it has not yet been measured.

The International Boundary Surveys have comprised the survey of the 141st Meridian, and that of the boundary of the coast strip of Alaska, the re-survey of the 49th parallel and the re-survey of the 45th parallel.

After the determination of the initial azimuth at the crossing of the Yukon river, which was spoken of in my last annual report, had been completed, the 141st Meridian was produced south about 130 miles. Great care was taken to secure accuracy, and a special method of production, using a transit with micrometric eyepiece, was employed. A plane table survey, checked by photographs, based upon a triangulation was made of the country adjacent to the line, and a vista was cut out through the woods, where such were found. As the line production considerably outstripped these auxiliary operations, more force will be employed in the latter this year. It is intended also to place the permanent monuments this season at points indicated in last year's line production.

Mr. A. J. Brabazon had charge of the Canadian share of the work. In connection with this survey a line of levels will be run by Mr. D. H. Nelles, from Whitehorse to connect with the boundary line.

The survey of the coast strip boundary was divided into the following sections:—

A United States party, under Mr. Fremont Morse, made a triangulation up Glacier bay in order to determine the geographical position of the peak S. 7450, which lies to the northwest of the bay, and near the height of land between it and Alsek river. As the next peak to the west determined upon by the Tribunal, lies on the other side of Alsek river, and at a distance of about fifty miles from this one, and the two peaks are not intervisible, it was necessary to accurately determine the geographical positions of both peaks, in order that the important point where the boundary line crosses the Alsek river may be correctly placed. The more westerly peak was determined in the previous year by Mr. Morse, and an attempt was made to locate S.7450, from the Alsek river side, but unsuccessfully.

It was located by last year's operations, and this year Mr. Morse will proceed to the marking of the line at the Alsek. Mr. D. H. Nelles, D.L.S., accompanied Mr. Morse last year as the Canadian representative, Mr. Geo. White-Fraser, D.T.S., accompanied him this year.

Mr. O. M. Leland, of the U.S. service, determined the position of the peaks to the east of Lynn canal, continuing his work of previous years southward from White Pass, and completing the connection with the peaks already determined from Taku river. Two Canadian parties worked in the region between peaks 'P' and 'T' of the Tribunal. The Tribunal did not define the boundary line between these peaks, a distance of some 125 miles. By a supplementary agreement made in March, 1905, the line was defined as following from summit to summit of certain peaks, from peak 'P' which is north of Taku river, to a peak near Whiting river. Thence by the terms of the agreement the line is to go to 'T' by peaks to be selected by the Commissioners after survey, but not departing more than a specified distance from the straight line.

The line was surveyed in 1906 from Taku river to Whiting river by Messrs. J. D. Craig and W. F. Ratz, Dominion Land Surveyors. The work between Whiting river and peak 'T' involves, under the agreement, a topographical survey and map as a preliminary to the selection of peaks by the Commissioners.

With a view to the mapping of this region, Mr. Ratz last year proceeded up Stikine river until he found, at Flood Glacier, a suitable point of entrance into the mountainous region to the west. By the photo-topographic method, based on a triangulation, he developed the topography of the region near 'T' and north of it for a considerable distance. This year he continues this survey, proposing to enter the region at a point further north, approaching this time from the Pacific side at the upper end of the Endicott Arm of Holkham bay.

Mr. Greene, assistant to Mr. Ratz, completed the cutting out of the vista and its marking of the boundary line at the Taku and Whiting rivers early in the season, joining Mr. Ratz later on the Stikine river.

Mr. J. D. Craig's survey had for purpose the survey of the boundary joining the Tribunal peaks from Mt. Whipple, southeast of Stikine river to near Unuk river.

This part of the boundary lies among rugged mountains a considerable distance from the coast and, in part, on the eastern side of the watershed of Iskut river, a large tributary of the Stikine, coming from the southeast.

Mr. Craig entered this region by the way of Bradfield Inlet. He carried a triangulation from the U. S. Coast Survey triangulation up Bradfield river to connect with the boundary peaks. Considerable topographical work also had to be done, since the survey made by the Joint Commission in 1893 was in this region incomplete. Unfortunately many of the photographic plates exposed for the purpose of developing this topography were lost by the upsetting of a canoe in the river during the high water of the latter part of the summer. Every effort was made to recover the plates which were enclosed in stout tin cases, and subsequently a reward was offered for their recovery, but unsuccessfully. The loss affects a part of the topographical survey only, and not the triangulation for the determination of the boundary line.

As above stated, it was found that the line in part falls within the Iskut drainage. It was judged that the line would cross a southerly tributary of that river at a low altitude in a timbered valley.

It was not practicable to reach this part of the line from the Bradfield side, and this year Mr. Craig is on his way up the south branch of the Iskut to complete the survey of that portion of the line. Mr. Bates, one of his assistants, with a small party, will again ascend Bradfield river, to complete the topographical work, including that section of which the plates were lost last year.

The survey of the 49th parallel west of the Rocky Mountains was completed during the season, including the vista cutting, line measurements, topographical work and setting of the permanent monuments, but excepting a part of the triangulation through the Coast range. This is being done this year by Mr. E. T. de Coeli, a member of Mr. J. J. McArthur's staff.

A technical examination of the line tracing and the monuments to ensure accuracy was begun by Mr. Sinclair, of the U. S. Coast and Geodetic Survey, and Mr. N. J. Ogilvie, D.L.S. They completed this inspection from Osoyoos lake to the summit of the Rocky Mountains.

In July and August, in company with Messrs. O. H. Tittmann and C. D. Walcott, the U. S. Commissioners, I engaged in a general inspection of the work.

The re-survey of the 49th parallel east of the Rocky Mountains has been begun. Mr. McArthur, with a party, is working from Coutts eastward, under a tentative agreement with the U. S. Commissioners, whereby the survey is to be made in alternate sections, by each country, of 100 miles.

The re-survey of the boundary line between Quebec and Vermont, the so-called 45th parallel has been completed. This work has been done by a joint party under Mr. G. C. Rainboth, D.L.S., and Mr. J. B. Baylor, of the U. S. Coast and Geodetic Survey. It comprises a re-survey of the line, clearing out the vista, re-setting the old monuments, and placing numerous new ones to meet the needs in that respect, and making a topographical survey, by plane table, of a belt extending one mile on each side of the line.

The re-survey has been begun this spring, under Messrs. Rainboth and Baylor, of the line between Maine and New Brunswick, northward from the source of the St. Croix river.

Owing to the increase in the surveying work, both of the boundary surveys and the Geodetic Survey, the office space in the observatory was found altogether insufficient. It was therefore decided to provide quarters elsewhere for the former, and rooms were rented in the Trafalgar block, at the corner of Bank and Queen streets. These have been occupied during the winter.

Appended hereto will be found the following:—

Appendix 1.—Report by Otto Klotz, LL.D., on seismological and magnetic work.

Appendix 2.—Report by J. S. Plaskett, B.A., on the astrophysical work.

Appendix 3.—Report by R. M. Stewart, M.A., on meridian work and time service.

Appendix 4.—Report on observations for latitude and longitude by J. Macara, Chief Computer.

Appendix 5.—Report of work done in the photographic division.

Appendix 6.—Description of a method for determining, from radial velocity observations, the elements of the orbit of a binary system, with tables by W. F. King, LL.D.

Appendix 7.—Report by C. A. Bigger, D.L.S., on the geodetic survey.

I have the honour to be, sir,

Your obedient servant,

W. F. KING,

Chief Astronomer and Boundary Commissioner.

APPENDIX 1.

REPORT OF THE CHIEF ASTRONOMER, 1908.

SEISMOLOGY, TERRESTRIAL MAGNETISM AND GRAVITY

BY

OTTO KLOTZ, LL.D.

CONTENTS.

ILLUSTRATIONS.

APPENDIX 1.

SEISMOLOGY, TERRESTRIAL MAGNETISM AND GRAVITY, BY OTTO KLOTZ, LL.D.

OTTAWA, ONT., April 1, 1908.

W. F. KING, Esq., B.A., LL.D.,
Chief Astronomer,
Department of the Interior,
Ottawa.

SIR,—I have the honour to submit the following report on the work carried out under my charge:—Seismology, Terrestrial Magnetism and Gravity, for the period July 1, 1907 to March 31, 1908, the latter date being the end of the newly adopted fiscal year.

SEISMOLOGY.

The Bosch photographic seismograph has been in continuous service and has given satisfaction. However, constant vigilance is necessary, as with all instruments when high efficiency is desired.

The source of light for the reflected beam from the small silver mirror at the point of support of the pendulum is from an alternating 104-volt current. As the observatory machine shop is run from the same circuit, the intensity of the light suffers some variation, depending on the running of the machinery. The light itself is from a single filament; the ordinary commercial electric lights with looped filaments are inapplicable as the image can not be condensed to a point or small spot of light on the sensitive paper on which the photographic record of the seismograph is made. It is found necessary to obtain these single filament lights in Germany (from Siemens & Halske), as none are made in Canada or the United States.

It may be interesting to record the following occurrence. Recently some fresh lamps were received of 25 c. p.; they were similar, but not identical with those used for the past two years. The glass tube is of somewhat larger diameter, the single filament is 22·5 cm. long, and the upper end is, as in the former case also, attached to a spiral spring, but of less than half the length of the other and open wound, having six coils. In both cases the return is by an outside thin uncovered twisted copper wire. The images as seen at the box surrounding the cylinder or drum are each about 2 cm. —long straight lines; these are condensed by a cylindrical lens to two small light spots on the photographic paper. When the new light was installed it gave a bright white light. It has been found with all the lamps that although they give a white light at first, in a very few hours it becomes reddish, and then remains fairly constant for weeks. The first day's record was satisfactory with the new light, but on the second day after recording for about five hours normally, both records (of the two pendulum mirrors) suddenly widened from a fine black line to a blurred one about 3 mm. wide, and continued so, with the exception of an hour or so when the usual black line was made. To be able to read the record or have a time-scale, the light is cut off by closing the slit every minute for two seconds. The seismogram had a startling appearance (Plate 1), it looked like a brick wall, the blurring was just about the width of the thread of the screw on the cylinder by which it is moved laterally, thus making the record look solid, with the minute-breaks for mortar. The cause of the trouble was

not at once apparent. A new lamp was installed; it behaved well for a day, and then the same trouble arose. By this time it was evident that the phenomenon was produced by the vibration of the filament. From the above data it will be noticed that the filament of the new lamp is a little longer (2·5 cm.) than that of the old lamp; that it is attached to a shorter spiral spring, and does not pass through a narrow glass neck within the glass tube. The next question was, what sets the filament in vibration? All possible external causes—earth tremors, mechanical disturbances of whatsoever nature—received due consideration and comparison with the record, but were all ruled out of court, so that by the principle of exhaustion and elimination, the electric current itself was left as the disturbing factor. The current, as stated, is an alternating one, with 120 alternations to the second, the variation of which is confined to a few per cent,—less than five. The alternating current passing through the spiral spring (which may be likened to a solenoid) produces a magnetic effect so that the convolutions are alternately attracted and released, that is, the spring opens and closes with each alternation like an accordion or concertina and this action is more or less reciprocated by the filament, especially if its period of vibration is coincident with the number of alternations per second. To assure myself that the position of the outside copper wire, lying along the glass tube, played no part whatever on the phenomenon, I cut it and led away one end straight up and the other straight down, by means of a long covered wire, but without producing any effect. I had the lamps removed to my room, set up on a frame and connected with the electrolier and the current turned on in order to watch the behaviour of the light. For a day or two they resented, apparently, the exposure. I then applied two bar magnets on opposite sides of the middle of the glass tube putting thereby the current in the magnetic field, when one of the filaments went into violent vibrations. The light presented two phenomena in the subsequent experiments, sometimes, but far less frequently, it appeared as a bright spindle; but more generally it had the appearance of a bright ribbon, tapering at both ends, a section of a spindle. When oscillating in this ribbon form, it readily responded to the approach of the magnets and would follow them, the plane of vibration being at right angles to the line between the magnets. This response could be effected too by a single magnet held perpendicular to the filament and 30 or 40 cm. away. The position of rest that the oscillations assumed was not quite indifferent, although not confined to one invariable position. The position assumed seemed dependent upon the plane of the spiral spring, *i.e.*, either in the plane or normal to the plane of the tilt. When withdrawing the magnets, the ribbon light would oscillate bodily, as if on pivots, for a few moments before coming to its position of rest. When both magnets, with opposite poles, were close to or in contact with the glass tube in opposite sides respectively, and kept there, then the oscillations were of the spindle form and not that of a ribbon. A gentle tap of the glass tube would assist in starting the oscillations under the influence of the magnets, and a sharper tap, at times, without the magnets produced the same result, that is, in starting the vibrations of the filament. From the phenomena that have been observed it would appear then that the light begins to vibrate when left to itself when everything is tuned, so to speak, to respond to the inherent note of the filament, that is, the alternations, the spiral spring and filament must be in unison. The behaviour of the light under the influence of the magnets is a very pretty phenomenon.

Attention may be drawn to another point of the record of the oscillation. It is well known that with photographic records of earthquakes as the amplitude increases the records become fainter and fainter, due to the rapidly moving light spot, until no record is seen save faint spots at the turning points of the forward and backward swing of the light spot, there being a momentary rest at the turning point and hence the photographic effect. For this same reason the edge or range of these very rapid oscillations, that have been under discussion above, will be photographed more intensely, and the edge or margin will appear darker as is seen in the diagram (Plate 1). It is

needless to say that the lamps that are responsive to the alternations are useless for recording purposes. The cure is new and shorter lamps.

One of the prime requisities in the study of seismograms is a thoroughly accurate time-scale, besides having the scale of such ratio that time may be read to individual seconds, this latter may be done when the scale is 15 millimetres to the minute, as is provided on many of the modern instruments. But with reference to the time itself, there is room for considerable improvement. It is unnecessarily burdening the difficult problems of seismology when the utmost confidence can not be placed on the time record. The studies of seismic disturbances have now advanced to that stage that an accuracy to a second is demanded. The most satisfactory arrangement is to have the time-recording mechanism of the seismogram in electric circuit with a standard mean time clock, itself under control by a master clock, as is the case with our instrument; there should then never be any correction of the magnitude of a second to the seismogram. Time records which only indicate the hours, obviously no longer meet the requirements of investigations of the present day.

Another point about time records that is not yet universally satisfactory is the want of co-ordination with reference to Greenwich, the prime meridian for international time. All records should be expressed in standard time, and not in local time, that is, the time adopted for the time scale of the seismogram in every country should differ from Greenwich time an even hour or hours. This avoids confusion not to say annoyance in the inter-comparison of records.

Various writers on seismology have made reference to the observations made by F. Napier Denison at Victoria, B.C., the results of which were published in the Quarterly Journal of the Royal Meteorological Society No. 120, October, 1901, under the title 'The Seismograph as a Sensitive Barometer.' The Milne horizontal pendulum there is mounted, p. 293, 'upon a concrete pier rising from the water's edge.' Let it be noted here that the water's edge is that of Victoria harbour, subject to the influence of the tides to be noted hereafter. Mr. Denison had, p. 294, 'frequently found that in the course of twenty-four hours the boom would swing off the photographic paper, and to bring it into its proper position it was necessary to alter the levelling adjustment.' To study the phenomenon 'wanderings of the boom' accurate measurements were made of the position of the boom, and tri-daily observations of the barometer, also tri-daily records of the direction and velocity of the wind and precipitation were made. From them, p. 295, 'it was found that the diurnal change was most pronounced during periods of high barometric pressure, as is usual during the summer months, while shortly before the passage of areas of low pressure across the province from the Pacific, the diurnal change would be completely masked by the steady easterly movement of the boom. These plottings were then studied in conjunction with our bi-daily synoptic weather charts for the corresponding period. From this comparison the following results have been deduced:—That when the barometric pressure is high over the Pacific slope from British Columbia to California, while off the Pacific coast the barometer is comparatively low, the horizontal pendulum tends to move towards the eastward. This movement appears to be due to distortion of the earth's surface, caused by the heavier air over the Pacific slope depressing the underlying land-surface below its normal position, while, on the other hand, the comparatively light air over the adjacent ocean tends to allow the sea and earth beneath to rise above its normal level; hence a horizontal pendulum as delicately poised as the one under discussion will, under these conditions, swing towards the region of greatest terrestrial depression, provided it be free to move in that direction. This theory of the earth's distortion under unequal atmospheric pressures is borne out when cases during these three months are taken, when the barometer is high over the ocean and a trough of low pressure covers the Pacific slope and Rocky Mountains, then the boom is found to travel towards the westward and continue to do so until a change in the distribution of air pressure occurred.' It will be observed that the investigations that Denison carried

out were in connection with the tilting and not with vibrations of the earth's surface; tilting caused by an unequal pressure or weighting of the surface. In the whole of the paper not a word is said about the effect of tides, although the instrument is within stone's-throw of the tide line. Further on we read, p. 297: 'It has been found that when an extensive storm area is approaching from the westward, and often 18 or 24 hours before the local barometer begins to fall, the pendulum swings steadily to the eastward, completely masking any diurnal fluctuations that might have existed, as the storm area approaches; and in the event of it being followed by an important high area, the pendulum will begin to swing towards the westward before it is possible to ascertain this area's position on the current Weather Charts. The principle already stated, that areas of heavy and light air cause a distortion of the earth's surface under which they prevail, is proved conclusively by types similar to the above illustration.'

With reference to the effect of the moon upon the solid crust of the earth we may refer to Sir G. H. Darwin*: 'The various effects which the moon may exercise on a pendulum are very complex. First, as regards simplicity, is the effect of the force to which the oceanic tides are due. If the earth were absolutely stiff and unyielding, this tide-generating force would produce a periodic oscillation of the pendulum of an amplitude which can be calculated with a close degree of approximation. That amplitude is so small that the measurement of it, even by the most delicate instruments, is a matter of the greatest difficulty. But in the second place the moon's tide-generating force acts not only on the pendulum, but also on the earth; and as the earth cannot be, as a whole, absolutely stiff, it must yield to the force. If it yielded as freely as water, the earth's surface would necessarily be perpendicular to the pendulum, and the pendulum would remain at rest. But it does not yield with perfect freedom, and therefore, in as far as it yields, its movement imparts to the pendulum an apparent deflection which tends to mask the true deflection due to tide-generating force. Lastly, at places within a few hundred miles of the sea, the varying load of the oceanic tide must produce a deflection of a pendulum, which is partly real and partly apparent. The real portion is almost certainly by far the smaller; it is due to the direct attraction of the sea, which will vary in intensity with the alternations of high and low water. The apparent portion is due to the warping of the superficial strata by the varying load of the tide, the slope being towards the sea at high water, and away from it at low water.'

Victoria lies at the eastern end of the straits of Juan de Fuca, which have an average width of about 15 miles, and is distant from the broad waters of the Pacific ocean about 70 miles. The Spring tides at Victoria vary between 7 and 10 feet, while the Neaps vary between 5 and 8 feet. On the other hand the barometric variations during the year lie within a range of 1·5 inches. The work of Denison shows undoubted care and considerable labour in making the many measurements, but it is questionable whether his results warrant the conclusions arrived at. The writer undoubtedly believes that change of atmospheric pressure can be read by a sensitive seismograph, but at the same time has very grave doubts as to the interpretation of the 'wanderings of the boom.' The point under discussion does not refer to pulsations or oscillations in the earth's crust, but to the bending of the same under varying loads, thereby causing a change in position of the pendulum zero. For an observing station on the sea-coast where the tide ebbs and flows, and the rise and fall is measured in feet, it is obviously wanting in completeness of investigation to ignore the effect caused by the loading and unloading of the coast line and sea bottom by the tides and deal only with the changing atmospheric pressure. Atmospheric pressure is equivalent to about fifteen pounds per square inch when the barometer stands at thirty inches, *i.e.*, for a fall of one inch in the barometer the atmospheric pressure is reduced by half a pound. Now a fall of one inch (25 mm.) is not a very common occurrence within 24 hours, yet during that time the immediate

* Seismology: Milne p. 263.

coast and sea-bottom have been loaded once or twice with a wedge of water, having a base of several feet in height. This tidal load may be compared to an area of high barometer. The specific gravity of sea-water is about 64 lbs. to the cubic foot, and hence the pressure per square inch of a column one foot high is slightly over half a pound, *i.e.*, it is fully as much as produced by a change of atmospheric pressure indicated by a fall of one inch of the barometer at sea-level. Now the amount of bending of the earth's crust is dependent not only upon a difference of pressure, but also upon the gradient, in other words, upon the relative position of the isobars. Examining our Weather Maps, it will be found that isobars differing by one-tenth inch and at distances apart of 150 miles are considered to give pretty steep gradients, so that to give a difference of one inch the barometric 'high' will cover an area 3,000 miles in diameter; or we may say that the distance between an area of high and one of low barometer, differing by one inch in pressure, will be approximately 1,500 miles. Even disregarding the tides at Victoria itself, which are on an average 8 feet, *i.e.*, considering the straits of Juan de Fuca as land, we cannot get away from the fact that at a distance of 70 miles, less than half the distance we have assumed for a steep gradient between isobars differing by one-tenth inch barometric pressure, we have the broad waters of the Pacific loading and unloading the continental coast and the sea-bottom with a volume of water, that may be safely assumed as being two feet in depth. It must be obvious, that as far as the bending of the earth's crust is concerned, the latter is subject to greater stresses in the vicinity and along continental coast lines by virtue of the rise and fall of the tides than through variations in atmospheric pressure. And hence to study for a coast station the bending of the earth's surface due to difference of atmospheric pressure without taking into consideration the tidal effect, would necessarily seem to lead to conclusions based on inadequate data. It may be observed that as the Milne pendulum is mounted north-south, and the co-tidal lines of the North Pacific along the American continent have a general north-south direction, the pendulum will thereby receive its maximum effect, as the 'wanderings of the boom' are east and west. Another point may be referred to, and that is the effect of variation of barometric pressure upon the water, upon the tides. A high barometer will decrease the height of the tide, and the effect may be taken at about one inch of the mercury column to one foot of water. Hence the combined effect of barometric and tidal pressures may in one case increase and in another decrease the bending effect of either.

As there is as yet little definitely known about the relationship between atmospheric pressure and the zero position of a horizontal pendulum, and furthermore there is a divergence of opinion among those who have occupied themselves with the subject, it was considered that in the interest of the important question involved, the weak points in the Victoria investigation should be referred to.

The graph which Denison constructs from measurements of the 'wanderings of the boom' for the year 1899, he studies by 'carefully examining the Victoria bi-daily Weather Charts, which cover the above-mentioned land area, and also the monthly charts of normal barometric pressure published in the Summary of the International Meteorological Observations from 1878 to 1887 (Washington). Referring to the Victoria Weather Charts for January, 1899, we find an abnormal amount of high barometric pressure prevailing over the Pacific slope from northern British Columbia southward to California, while off the coast at this latitude the normal winter low pressure remained constant. The combined influence of the heavier air over the Pacific slope and diminished pressure over the ocean probably caused the abnormal easterly movement of the pendulum during this month.'—In the first place, referring to the above quotation it is not at all clear what the normal barometric pressure for the period 1878 to 1887 has to do with the barometric pressures for 1899, the ones to which the pendulum movements are supposedly due. It is a question of cause and effect; what the pressures were in any other year than 1899 can not move the boom in 1899. In the next place, the statement that in January 'an abnormal amount of

high barometric pressure prevailed over the Pacific slope' does not appear quite accordant with the data in the 'Report of the Meteorological Service of Canada' for 1899. In that report there are four stations given for the Pacific coast in British Columbia from latitude 54° 34′ to 48° 24′, viz.: Port Simpson, Rivers Inlet, Carmanah and Victoria, for which the monthly mean, maximum and minimum pressures are given. It is found that in every case the monthly mean for January is not greater than the annual mean, so that the 'abnormal amount of high barometric pressure' is not apparent. The following are the figures taken from the report:—

	Mean for Jan.	Mean for year.
	Inches.	Inches.
Port Simpson	29·76	29·81
Rivers Inlet	29·89	29·95
Carmanah	29·79	29·82
Victoria	29·94	29·94

Data for the Pacific coast south in the United States are at the moment not available. It may be observed that as the pendulum is mounted north and south, areas of high and low barometer must lie east and west of each other to affect the pendulum materially, for the zero position of the pendulum would not be sensibly affected were those areas north and south respectively, of the station. From the preceding short presentation it would appear, therefore, that the conclusions arrived at by the investigation of Denison at Victoria in 1899 must be taken with reserve. It is not denied that the fact may be established that the 'Seismograph is a sensitive barometer,' but if such a conclusion is arrived at by observations at a station on the sea-coast, the effect of the tides as well as the weighting or loading effect influenced by coastal configuration of the change of level of the water due to difference of atmospheric pressure must enter into consideration.

Earthquakes Recorded.

The official year began with an earthquake in the forenoon of July 1, 1907. The seismogram gives the following data:—

(Time is expressed in Greenwich Mean Time, counting from midnight to midnight, the hours, *i.e.*, from 0^h to 24^h.)

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began	13	15	49	13	15	49
Second preliminary tremors began	13	18	14	13	18	38
Principal portion began	13	21	08	13	21	14
Duration of earthquake		59	00	1	02	00
Maximum amplitude		4^{mm}			4^{mm}	
Period of pendulums		$5^s{\cdot}7$			$5^s{\cdot}7$	
Magnification		120			120	

This quake was neither preceded nor succeeded by any earth tremors, the trace of light point being a perfectly straight line up to the time of the arrival of the preliminary tremors, which gave a greater (4mm) amplitude to the N. S. component than to the E. W. Component (2·5mm). The former showed two maxima markedly, while the latter showed only one. The beginning of the second preliminary tremors is somewhat uncertain on account of the occurrence of two, if not three, distinct minima for the N. S. component. The amplitudes for the phase of the second preliminary tremors is for each pendulum only about one-half that for the first preliminary, which is rather the reverse of what usually obtains.

For the 'principal portion' the amplitudes for the E. W. component are somewhat greater than for the N. S., the former being 4mm, the latter 3mm. In the latter part of the principal portion the superposition of the harmonic motion of the pendulum and of the periods of the earth's particles in the quake motion is well shown, (Plate 1). The waves of the principal portion have a period of 20s. Judging the earthquake by the amplitude, the shock was greater than that recorded by the destructive Kingston earthquake. The distance from the epicentre was estimated at about 3,500km. It may be remarked that a circle described with a radius a little greater—say 3,800km—will pass through Iceland, Azores, the Windward Islands of the West Indies, will skirt Central America, Mexico on the Pacific side and pass through and along the west of California. On this arc of over three-quarters of a circle, we find many seismic areas, so that even when we can interpolate the distance from a single seismogram accurately, when it happens to be near the above distance it is more difficult to suggest the locality than when the distance is such that confines the probable place to a single known seismic area.

The next earthquake record was on the morning of August 8, 1907. The earth began to show unrest from 10 p.m. on August 6, and set up the characteristic 'saw-tooth' tremors which continued until relieved or neutralized by the small quake thirty hours afterwards. In this case the cause or origin of the earth tremors seems very clear, for the barogram (20cm equals a week) for that week shows a zigzag line, (range 1mm) beginning shortly after 10 p.m. of August 6, dropping from 756mm to 753mm in 15 hours, and then rising with less fluctuation to 760mm in 18 hours, whereafter the pressure remained fairly constant for the following day. There does not seem to be any doubt that the barogram and seismogram are records of the same phenomenon, the former showing directly the rapidly varying atmospheric pressure, while the latter showed the effect of that varying pressure in causing pulsations to be set up in the crust of the earth. When the barogram shows rapid fluctuations we can frequently find the effect on the seismogram, although there are exceptions, notably in the twelve hours forenoon of April 30, last, when the barogram showed some twenty fluctuations in that time, and just before noon dropped suddenly over 2mm, yet the seismogram showed no disturbance. It is perhaps correct to assume that the earth's crust has for any given area an inherent period of vibration, and when the rapid fluctuations of atmospheric pressure synchronize with the former, or the period of one is a multiple of a period of the other, then will the oscillation of the surface of the earth be more marked than would otherwise be the case.

For the above quake the amplitudes of the first preliminary tremors were about the same as those of July 1, and relatively too for the two pendulums, but the whole quake only lasted about 15 minutes, followed by small earth-tremors, smaller in amplitude than those which preceded the quake, for several hours until quiet was restored. The following are the data:—

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began......	9	23	20*	9	23	18*
Second preliminary tremors began....	9	25	12	9	25	14
Principal portion................	9	25	56	9	25	52
Duration of earthquake............		11	00		12	00
Maximum amplitude..............		3mm			1·6mm	
Period of pendulums..............		5s·7			5s·7	
Magnification..................		120			120	

*Greenwich Mean Time.

Then followed the quake at noon of August 17. Before the quake, minute earth tremors, ·2mm amplitude, for some hours manifested themselves. When the earth

is in a state of unrest it is not always easy to recognize the beginning of the first preliminary tremors, when the impulse was either not great to begin with, or when the epicentre is very distant. The present one is a case in point.

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began......	17	38	07*	17	38	07*
Second preliminary tremors began....	—	—	—	—	—	—
Principal portion began............	17	47	06	17	47	05
Duration of earthquake............		47	00		50	00
Maximum amplitude..............		1mm			1·6mm	
Period of pendulums..............		5s·7			5s·7	
Magnification..................		120			120	

*Greenwich Mean Time.

The Press reported a despatch from Laibach, Austria, 'A violent distant earthquake was recorded at the observatory here on Saturday night, beginning 6h 38m, and lasting 50 minutes.' The time would be equivalent to 5h 38m p.m. Greenwich time, or as is generally expressed, 17h 38m G.M.T., so that the record seems to be of the same earthquake.

On the afternoon of August 22, 1907, the seismogram showed the occurrence of an earthquake. For hours before, the earth had been almost perfectly quiescent. The records of the first impulse by the two pendulums are fair reciprocals of each other. While the N. S. component showed a maximum amplitude of 1·7mm at the beginning and then decreased, the E. W. component did the reverse, within 40 seconds, amplitude 2·2mm.

The data are:—

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began......	22	41	00*	22	40	56*
Second preliminary tremors began....	—	—	—	—	—	—
Principal portion................	22	52	00	22	52	04
Duration of earthquake............		26	00		31	00
Maximum amplitude..............		1·7mm			2·2mm	
Period of pendulums..............		5s·7			5s·7	
Magnification..................		120			120	

*Greenwich Mean Time.

The second preliminary tremor was not clearly recognizable as such and hence no time is given therefor.

One of the best seismograms yet obtained here was that of the earthquake of September 2, 1907, as shown on the accompanying copy (plate 5). The data are:—

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began......	16	12	19*	16	12	18*
Second preliminary tremors began....	16	21	28	16	21	12
Principal portion................	16	28	32?	16	28	36?
Duration of earthquake............	2	55	00	3	00	00
Maximum amplitude..............		15mm			13mm	
Period of pendulums..............		5s·7			5s·7	
Magnification..................		120			120	

*Greenwich Mean Time.

At 16h 35m both pendulums begin slow oscillations with large amplitudes, about 10mm, and period of approximately 24 seconds, these continue with more or less regularity, with, however, constant diminution of period, for about half an hour, when the period is approximately 13 seconds. It will be observed that the intervals between the 1st P. T. and the 2nd P. T., and the P. P. are not in the ratio fairly well known for distant earthquakes; the interval between the 2nd P. T. and the P. P. being too small. The record between 16h 28m and 16h 35m undoubtedly shows undulatory waves of a period of fully 40 seconds, which after 16h 35m, no longer show the undulatory characteristic, but simply of pulsatory waves of long period as already indicated above. Attention may be drawn to another feature of the diagram, and that is, to several distinct pulsations for both pendulums between the 1st and 2nd P. T. (preliminary tremors). Some seismologists explain this phenomenon as being produced by reflection at the earth's surface of the longitudinal wave, once or more times. The explanation is plausible, but far from obvious. It may be due too to the fact that the earthquake or debacle at the hypocentre is not one crash, but there may be several, following each other at short intervals, at such intervals, that for distant stations their impulses may arrive before the arrival of the transverse waves or second preliminary tremors, in which case their records would be readily identified on the seismogram.

On September 23, in the afternoon, a well-marked earthquake was recorded. With most earthquakes, or more specifically, their seismograms, the most readily recognizable feature is the arrival of the first preliminary tremors, especially if the earth has been in a state of rest and no earth tremors immediately precede the quake. On the above date, the earth showed no signs of unrest, the seismograph was recording straight lines, yet the beginning of the 1st P. T. shows no easily distinguishable offset, but instead the merest departure, this latter is particularly the case for the E. W. component, which throughout shows a smaller amplitude, from which one might infer that the epicentre had a more southerly than easterly or westerly direction from here. I advisedly say southerly instead of 'southerly or northerly' as the archaean country to the north of us, is, as far as known, free from earthquakes. The period of the principal portion of the maximum amplitude is for both pendulums 9s, which in a few minutes later diminished to 7s. The following are the data:—

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began......	21	51	09*	21	51	09
Second preliminary tremors began....	21	57	30	21	57	36
Principal portion................	—	—	—	—	—	—
Duration of earthquake...........		50	00		50	00
Maximum amplitude.............		15^{mm}			12^{mm}	
Period of pendulums.............		$5^{s}\cdot7$			$5^{s}\cdot7$	
Magnification.................		120			120	

*Greenwich Mean Time.

On the forenoon of October 16, 1907, a severe earthquake was recorded. The behaviour of the two pendulums was decidedly different for the first preliminary tremors. In the first place, it may be noted that preceding the quake the earth showed but very minute earth tremors, so that the arrival of the 1st P. T. could scarcely be obscured by them, as sometimes happens. While the E. W. component shows a decided abrupt amplitude for the first impulse, and a period of 5s·7, which is the period too of the pendulum, the N. S. component shows but very minute oscillations of about 3s·3 period, and these persist for nearly six minutes with slightly increasing distinctness, until a change in their character supervenes. These minute oscillations, of about half the period of the pendulum for the N. S. component, can be seen too here and there in the seismogram for hours before the quake, and which are recognized as 'earth

tremors.' The earth tremors on the E. W. component are never shown to be of such short period, but are always practically the period of the pendulum. After the beginning the E. W. component oscillates fairly regularly, period 5s·7 with varying amplitudes up to 6mm. until 14h 10m 14s G.M.T., when wave interference takes place. This wave interference takes place on the other, N. S., component a minute earlier, at 14h 09m 12s G.M.T. Henceforth the regularity of the oscillations for both components is more or less interrupted, until at 14h 15m both pendulums start such wide oscillations that with a somewhat weak light the photographic record is no longer continuous. This condition obtains for about seven minutes, when again the amplitudes are fully recorded. Although for the first preliminary tremors the N. S. component seemed less responsive to the waves than the E. W. one, yet when the principal portion sets in, and onward to the end of the quake, its amplitude is fully as large as that of the other for the corresponding time. The following are the data:—

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began......	14	04	00?*	14	03	50*
Second preliminary tremors began....	14	09	12	14	10	14
Principal portion................	14	14	40	14	14	44
Duration of earthquake............	2	00	00	2	00	00
Maximum amplitude..............		24mm			24mm	
Period of pendulums.............		$5^s·7$			$5^s·7$	
Magnification..................		120			120	

*Greenwich Mean Time.

As this severe earthquake was not recorded by the Press it must have occurred either in the ocean or in uninhabited parts. The distance estimated, 4,800km, about 3,000 miles, would appear to make the disturbed area near the boundary line between Colombia and Ecuador.

A few days later, about midnight of Sunday, October 20-21, 1907, occurred another marked earthquake. The earth had been in a state of unrest and tension since Saturday, as shown by the earth tremors recorded by the seismograph, and which made it difficult to determine, at least for the E. W. component, the accurate time of arrival of the first preliminary tremors. The seismogram immediately showed that we were dealing with a very distant disturbance. It is generally found that the greatest amplitude is attained after the arrival of the long period surface waves, when the pendulum no longer retains its theoretical position of a steady point, but is set oscillating. In this case we have the maximum amplitude 10mm for N. S., 5mm for E. W. component, occurring immediately after the arrival of the second preliminary tremors, which are well marked, more so than the beginning of the succeeding long period surface waves. Comparing the earth tremors for several hours preceding the quake with those several hours afterwards, it is found that there is practically no difference.

An earthquake is always a neutralizing of the stresses set up in the earth, a restoration towards a state of equilibrium, and hence in the epicentral area we should expect no earth tremors, as far as they are not due to barometric or atmospheric variations. However, distant earthquakes could scarcely affect local stresses, not due to external causes, and hence earth tremors are recorded after as well as before the quake as in the above case. The following are the data:—

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began......	4	37	00?*	4	37	00
Second preliminary tremors began....	4	47	24	4	47	24
Principal portion...............	4	57	28?	5	00	16?

Duration of earthquake..........	1 25 00	1 25 00
Maximum amplitude.............	3^{mm}	2^{mm}
Period of pendulums.............	$5^{s}\cdot 7$	$5^{s}\cdot 7$
Magnification.................	120	120

*Greenwich Mean Time.

It is to be observed that the above tabulated maximum amplitude refers as heretofore to the principal portion or surface waves. As has already been noted in this particular quake the amplitudes of the transverse waves, 2nd preliminary tremors, are the greatest.

It was estimated that this quake was distant at least 9,000km. Press despatches the following day brought the news of a most disastrous earthquake in central Asia near Samarkand, of which we in Ottawa here had such a complete record. Not only was the earthquake very destructive as far as buildings are concerned, but hundreds of lives were sacrificed too.

In the early hours of December 30, 1907, a severe earthquake was recorded, making a particularly fine seismogram. The earth had been almost wholly free from earth tremors preceding the quake, so that there was no interference phenomenon, and the arrival of the first preliminary tremors is well marked. From the intervals to the second preliminary tremors and the beginning of the principal portion the distance to the epicentre was found to be 4,000km. The quake lasted for nearly two hours. The following are the data:—

		N. S. Component.			E. W. Component.		
		h	m	s	h	m	s	
First preliminary tremors began......		5	33	48*	5	33	48*	
Reflection.....................		5	35	08	5	35	10	
Second preliminary tremors began.. ..		5	39	24	5	39	20	
Principal portion.................		5	43	40†	5	44	00†	
Maximum portion.........	$11\cdot 5^{mm}$	5	50	00†	5	47	40†	$15\cdot 5^{mm}$
Duration of earthquake...........		1	40	00	1	40	00	
Maximum amplitude..............			12^{mm}			16^{mm}		
Period of pendulums..............			$6^{s}\cdot 3$			$6^{s}\cdot 3$		
Magnification.................			120			120		

*Greenwich Mean Time. †About.

Such clear and good records of an earthquake as the above seismogram when compared with similar ones from other and distant stations, will contribute much to the proper interpretation of the wave impulses.

A slight earthquake was recorded on the evening of February 1, 1908. It was at the time that the peculiar phenomenon of vibrations of the single filament of the electric light was experienced, so that the record is very blurred and difficult to read. The first preliminary tremors for both components arrived apparently at 23h 25m 20s G.M.T. The maximum amplitude was 6mm, and the quake lasted for 45 minutes.

During the night of February 8-9, two small earthquakes manifested themselves distinctly, but being of small intensity combined with the earth tremors that were present, it is somewhat difficult to recognize the various phases. With some uncertainty the following are the readings:—

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began......	3	28	12*	3	28	18*
Second preliminary tremors began.. ..		?		3	32	18

	h	m	s	h	m	s
Principal portion	3	34	48	3	35	00
Duration of earthquake		35	00		38	00
Maximum amplitude		2mm			3mm	

*Greenwich Mean Time.

There is a distinct oscillation lasting about 40s and beginning at 3h 23m 28s G.M.T. for the N. S. component, but the E. W. component shows absolutely no corresponding disturbance.

For the other and smaller quake we have:—

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began	9	15	08*	9	19	36*
Second preliminary tremors began	—	—	—	—	—	—
Principal portion	9	28	40	9	26	30
Duration of earthquake		16	00		23	00
Maximum amplitude		1mm			1·5mm	
Period of pendulums		5s·7			6s·3	
Magnification		120			120	

*Greenwich Mean Time.

The record for E. W. component is far better than that for the other, being sharper, hence discrepancy in reading the times.

Two days afterwards another slight quake was recorded. The first preliminary tremors arrived at 13h 09m 48s G.M.T. (February 11), the maximum amplitude being only 1mm, and the quake lasted about 16 minutes.

On February 14 two earthquakes were recorded; the data are as follows:—

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began	9	01	04*	9	01	20*
Second preliminary tremors began	9	08	20	9	08	18
Principal portion	9	14	00?	9	14	00?
Duration of earthquake		40	00		40	00
Maximum amplitude		4mm†			5mm†	
Period of pendulums		5s·7			6s·3	
Magnification		120			120	

*Greenwich Mean Time. †At 9h 08m 30s.

For the other quake:—

	N. S. Component.			E. W. Component.		
	h	m	s	h	m	s
First preliminary tremors began	11	44	28*	11	44	00?*
Second preliminary tremors began	11	47	08	11	47	14
Principal portion	11	48	08?	11	48	28?
Duration of earthquake		16	00?		16	00?
Maximum amplitude		3·5mm			3·5mm	

*Greenwich Mean Time.

From the time intervals of the different phases for each earthquake, it appears that they did not emanate from the same hypocentre, that for the latter being very much nearer than for the former. Subsequent, rather vague, press reports announced earth-

quake shocks about this time in the Azores, but the distance to the latter, being about the mean of the two deduced for the above, almost precludes a connection between the seismograms and the disturbances in those islands.

On March 3, 1908, the record showed the earth to be fairly quiescent, with the exception of a slight, yet well marked disturbance in the evening, lasting about 10 minutes. The nature of it makes it somewhat uncertain whether it was a slight earthquake or only a passing earth tremor, although the barogram gives no evidence of the latter. The disturbance began at 11h 48m and had an amplitude of 1·5mm.

On the following day, in the evening, a slight but distinct earthquake was recorded, especially by the E. W. component. As the disturbance was of small intensity, it is impossible to separate clearly the various phases. The following are the notes of the reading of the seismogram:—For the N. S. component we find as beginning, a faint trace at 2h 43m 24s (G.M.T. March 5), a distinct 'kick' at 2h 43m 35s, a slight disturbance between 2h 45m and 2h 45m 18s, a slight wave at 3h 25m; from 3h 26m to 3h 27m 14s three distinct waves, period 24s; last faint trace of undulating line at 3h 38m, period 20s?. For the E. W. component the beginning is shown by a faint trace at 2h 36m 48s G.M.T.; it will be noticed that this is about 7 minutes earlier than recognized on the other component. The oscillations then recorded have a period of about 7 seconds and have the appearance of earth tremors. Between 2h 55m and 2h 56m there are slight irregularities, and between 2h 58m and 3h 03m well-marked oscillations of about 7 seconds period. From 3h 20m to 3h 28m begin long waves of 24 seconds period; shorter waves of 20 seconds period appear between 3h 40m and 3h 50m. End of quake was about 4h. Amplitude was 1mm. As already indicated the N. S. component scarcely responded to the disturbance. From a press despatch the following day from the seismological station at the Isle of Wight, where a 'very big earthquake' was recorded, beginning at 2h 30m, it would appear that the above is a record of the same phenomenon, and as the Isle of Wight record very materially (16 minutes by press report) precedes the one here, it is inferred that the epicentre must have been nearer to and east of the English station.

About 12 hours after the above, another small disturbance took place, which affected the two pendulums about equally. It does not show any characteristic of an earthquake by first and second preliminary tremors or principal portion, yet it is a very distinct disturbance, the record otherwise showing quiescence. It began at 14h 46m G.M.T. (March 5) and continued for 16 minutes, giving an amplitude of 1mm.

EARTHQUAKES RECORDED BY THE BOSCH PHOTOGRAPHIC SEISMOGRAPH AT OTTAWA, CANADA.

Date.	Component N.—S. or E.—W.	Greenwich Mean Time. First preliminary tremors began.			Second preliminary tremors began.			Principal portion began.			Duration of earthquake.		Maximum double amplitude.	Magnification of record.	Period of pendulum.
1907.	–	h.	m.	s.	h.	m.	s.	h.	m.	s.	h.	m.	mm.	—	s.
July 1	N.—S.	13	15	49	13	18	14	13	21	08		59	4	120	5·7
	E.—W.		15	49		18	38		21	14	1	02	4	120	5·7
Aug. 8........	N.—S.	9	23	20	9	25	12	9	25	56	0	11	3	120	5·7
	E.—W.		23	18		25	14		25	52	0	12	1·6	120	5·7
" 17	N.—S.	17	38	07	...	...	...	17	47	06	0	47	1	120	5·7
	E.—W.		38	07	...	...	...		47	05	0	50	1·6	120	5·7
" 22	N.—S.	22	41	00	...	...	...	22	52	00	0	26	1·7	120	5·7
	E.—W.		40	56	...	...	...		52	04	0	31	2·2	120	5·7
Sept. 2.......	N.—S.	16	12	19	16	21	28	16	28	32?	2	55	15	120	5·7
	E.—W.		12	18		21	12		28	36?	3	00	13	120	5·7
" 23.....	N.—S.	21	51	09	21	57	30	...	...	...	0	50	15	120	5·7
	E.—W.		51	09		57	36	...	...	...	0	50	12	120	5·7
Oct. 16........	N.—S.	14	04	00?	14	09	12	14	14	40	2	00	24	120	5·7
	E.—W.		03	50		10	14		14	44	2	00	24	120	5·7
" 21.......	N.—S.	4	37	00	4	47	24	4	57	28?	1	25	3	120	5·7
	E.—W.	4	37	00?	4	47	24	5	00	16?	1	25	2	120	5·7
Dec. 30........	N.—S.	5	33	48	5	39	24	5	43	40*	1	40	12	120	6·3
	E.—W.		33	48		39	20		44	00*	1	40	16	120	6·3
1908.															
Feb. 9.......	N.—S.	3	28	12		?		3	34	48	0	35	2	120	5·7
	E.—W.		28	18		32	18		35	00	0	38	3	120	6·3
" 9.......	N.—S.	9	15	08	...	...	...	9	28	40	0	16	1	120	5·7
	E.—W.		19	36	...	...	...		26	30	0	23	1·5	120	6·3
" 14........	N.—S.	9	01	04	9	08	20	9	14	00?	0	40	4	120	5·7
	E.—W.		1	20		8	18		14	00?	0	40	5	120	6·3
" 14........	N.—S.	11	44	28	11	47	08	11	48	08?	0	16?	3·5	120	5·7
	E.—W.		44	00?		47	14		48	28?	0	16?	3·5	120	6·3

* About.

Microseisms.

By this designation are included all pulsations not directly attributable to what are generally known as earthquakes, that is, of abrupt, more or less violent, and momentary movements of the earth's crust, the effect of which may, however, continue for some hours. Attempts have been made to classify these microseisms according to their cause, but so far without complete success. During the past year the writer has paid considerable attention to these disturbances, and in doing so has studied and compared the daily seismograms with our weekly aneroid barograms and also with the daily weather maps, which give the isobars at 8 a.m. for Canada and the United States, roughly between latitudes 25° and 55°, and the Atlantic and Pacific oceans. The

average time of the beginning of the seismogram sheet is about 10 a.m., so that the above isobars and gradients dependent upon them are for a time preceding the former by two hours. From the examination of the local barogram alone, not much information can be gathered as to the behaviour of the seismograph except when very rapid and marked fluctuations, say of a millimetre or more, take place in the pressure, comparable with the 'pumping' of a mercurial barometer at sea. The barometer may show little or no change in pressure at a given place, yet areas of high and low (barometer) may be rushing along to the north and south of it, setting up vibrations or pulsations of the earth's surface that may be markedly felt at the given place by the seismograph. Similarly from a large rise or fall of the barometer during 24 hours at a given place alone, we can draw no gradients to determine the atmospheric movements; the position of the isobars, and highs and lows being unknown. We have simply the record of the vertical movement of pressure at one point. In the following table are given the microseisms, although not when showing merely the faintest trace here and there, recorded between July 1, 1907, the close of the last annual report, to March 31, 1908, the close of the newly adopted fiscal year; also the state of the barometer for the respective day taken from the weekly barogram sheet of an aneroid; and lastly the position of the areas of 'high' and 'low' barometer at 8 a.m. of the respective day, taken from the daily weather maps covering Canada and the United States. The isobars are drawn at intervals of a tenth of an inch. The normal to the isobars is called the gradient, and when spoken of, generally refers to the gradient between a low and high passing through Ottawa. The maximum absolute amplitude of the microseism is expressed in microns (μ). It is to be noted that the beginning of each seismogram is about 10 a.m., that is, two hours after the time of the isobars of the weather maps.

The object of the tabulation is to show various phenomena of the same time, and trace if possible any connection or relationship between them. The word gulf refers to the Gulf of St. Lawrence. It may be observed that St. Johns is in Newfoundland and St. John in New Brunswick, as both places are referred to. For purposes of orientation of highs and lows, a blank weather map, plate 2, accompanies this report, in order that places referred to in the following tables may be readily identified. 'Steep gradient' signifies a difference of pressure of one-tenth inch in 150 miles or less. The other terms used under the column 'gradient' are based on the preceding scale.

Date.	Microseisms.	Barometer in mm.	High and Low areas.	Gradients.
1907.				
July 9	First since July 1....	Nearly constant	Low, 29·5, lower St. Lawrence.	Not steep.
" 29	Marked, 8μ...	Practically constant 750..	Low, 29·6, Gulf; low, 29·7, Abitibi, high 30·1, Denver	Long.
" 30	Marked, decreasing 11μ	Practically constant 750..	Low, 29·8, St. Lawrence; high, 30·1, Kansas and Bermuda.	Very long.
" 31	Marked, 13μ..... ...	Practically constant 750..	Low, 29·7, Montreal; high, 30·2, Wyoming and Bermuda.	Very long.
Aug. 14	Very minute	Gradually rising...... ..	Low, 29·5, Gulf; high, 30·4, Sault Ste. Marie.	Fairly steep.
" 16	Small, 4μ.	Gradually falling.	Low, 29·5, Port Arthur; high, 30·3 off Nantucket.	Fairly steep.
" 29	Small....	Constant 756......... .	Low, 29·6, Gulf; high, 30·0, Detroit.	Not steep.
" 30	Small, 4μ..	Slightly rising....	Low, 29·7, Gulf; high, 30·0, Port Arthur.	Not steep.
" 31	Well marked, 13μ. ..	Nearly constant 758.....	Low, 29·8, Gulf; high, 30·2, Sault Ste. Marie.	Fairly steep.
Sept. 3	Minute.	Nearly constant 754.....	Low, 29·8, The Lakes; high, 30·1, Gulf.	Fairly steep.

Date.	Microseisms.	Barometer in mm.	High and Low areas.	Gradients.
1907.				
Sept. 13	'Sawtooth' type.....	Nearly constant	Low, 29·8, Gulf; high, 30·3, The Lakes.	Fairly steep.
14	'Sawtooth', well marked.	Nearly constant	Low, 29·9, Port Arthur; high, 30·4, New Brunswick	Fairly steep.
18	Well marked	Falling.	Low, 29·4, off Newfoundland; high 30·4, Ottawa.	Steep.
19	Well marked, 8μ...	Falling......... . .	Low, 30·0, Newfoundland; high, 30·3, off Maine coast.	Long.
" 24	Small...............	Rapidly rising..	Low, 29·1, White River; high, 30·1, Bermuda.	Pretty steep.
25	Small, less than yesterday.	Rising	Low, 29·3, mouth St. Lawrence; high, 30·1, Bermuda; another, 30·3 Omaha.	Pretty steep.
30	Very strong, 25μ ..	Gradually rising. .. .	Low, 29·5, Sable Island, surrounded by steep gradients to coast; high, 30·0, Gulf; another, 30·3, St. Paul.	In part steep.
Oct. 1	Well marked, 12μ....	Nearly constant 761. .	Low, 29·8, Sable Island; high, 30·3, Toronto.	Pretty steep.
2	Well marked, but less than yesterday.	Slightly falling.....	Low, 29·6, off Sable Island; high, 30·2, Ottawa.	Steep in ocean.
3	Well marked, 15μ....	Rapidly falling to 743.	Low, 29·2, St. Johns; high, 30·2, Hatteras.	Very steep in Gulf but not on land.
4	Well marked, 9μ. . .	Gradually rising . . .	Low, 29·6, Newfoundland; Low, 29·5, Ottawa.	Not steep.
" 4	Diminish much following morning.	. . . . . .	High, 30·1, Bermuda.....	. . ..
" 7	Well marked, 13μ....	Falls 8 mm. and rises again to 750.	Low, 29·8, St. Lawrence to Texas; high 30·2, Wyoming and Bermuda.	Fairly steep.
" 9	Well marked, 13μ....	Gradually falling to 752..	Low, 29·6, Newfoundland; low, 29·7, Port Arthur; high, 30·2, New York	Steep in Gulf.
16	Slight increase to 16μ	Nearly constant 763. ...	Low, 29·7, Newfoundland; high, 30·4, Washington.	Steep in Gulf.
" 19	Slight increase to 10μ	Nearly constant 761. ...	Low, 29·8, Gulf; high, 30·3, Philadelphia	Not steep.
20	Well marked, 12μ and decrease.	Gradually rises to 765....	Low, 30·0, Chicago; high, 30·4, Winnipeg.	Not steep.
" 21	Strong, 21μ	Falls rapidly 12 mm....	Low, 29·5, Sable Island; high, 30·4, Detroit.	Very steep around low.
22	Very strong, 25μ. ...	Falls rapidly 5 mm., then rises.	Low, 29·1, St. Johns another, 29·6, White River; high, 30·3, off Norfolk.	Extremely steep in Gulf.
23	Very strong, 21μ.. .	Gradual rise to 762......	Low, 29·5, mouth of St. Lawrence; high, 30·1, Bermuda; high, 30·2, Port Arthur; high, 30·1, Galveston.	Steep.
24	Fairly strong, 11μ. ..	Falls 10 mm. to 752.. ...	Low, 29·6, Sable Island; high, 30·3, Toronto.	Fairly steep.
25	Strong, 17μ.........	Rapid rise to 766	Low, 29·8, Gulf; high, 30·2, Hatteras.	Not steep.
26	Fairly strong, 12μ ...	Falls to 756	Low, 29·7, Gulf; high, 30·4, Toronto.	Fairly steep.
27	Well marked, 8μ	Nearly constant 754.. ..	Low, 29·8, Georgian Bay; high, 30·4, Halifax.	Steep.
" 29	Fairly strong, 14μ..	Nearly constant 755. ..	Low, 29·6, off Boston; high, 30·3, Port Arthur; another Louisville, 30·2.	Steep around low.
30	Fairly strong, 12μ....	Gradually rising to 772.	Low, 29·4, Gulf; high, 30·4, Toronto.	Very steep.
" 31	Well marked, 9μ.....	Nearly constant 771. ...	....	....
Nov. 4	Slight, but increase to 16μ.	Nearly constant 754. ...	Low, 23·3, mouth of St. Lawrence; high, 30·1, Chattanooga.	Steep.

Date.	Microseisms.	Barometer in mm.	High and Low areas.	Gradients.
1907.				
Nov. 6	Slight, increase after 5 p.m. to 9 a.m. 21μ.	Rapid fall to 733........	Low, 29·7, Norfolk; high, 30·3, Gulf; another 30·1, Galveston.	Fairly steep.
" 7	Strong, 18μ	Rises rapidly to 751.. ..	Low, 29·1, Montreal; high, 30·2, Newfoundland; another, 30·1, Montgomery.	Exceedingly steep.
" 8	Fairly strong, 10μ....	Nearly constant 751. .. .	Low, 29·3, mouth St. Lawrence; high, 30·2, Jacksonville.	Fairly steep.
" 25	Very marked, 17μ....	Gradually falls 11 mm. to 750.	Low, 29·9, off New York; Low, 29·8, Port Arthur; high, 30·6, Gulf; high, 30·3, Vicksburg.	Steep on Atlantic coast.
" 29	Very strong, 25μ ...	Gradually rises to 765...	Low, 29·7, Gulf; low, 30·0, Jacksonville; high, 30·5, Salt Lake.	Not steep.
" 30	Marked, falling off, 14μ	Gradually falling to 760..	Low, 30·0, off Hatteras; low, 29·9, St. Louis; high, 30·3, Quebec.	Not steep.
Dec. 2	Marked, reading 17μ.	Rising 10 mm. to 765 .	Low, 29·2, Gulf; high, 30·5, Salt Lake.	Very steep in Gulf.
" 5	Become very strong, 21μ.	About constant, 759.....	Low, 29·8, off New York; high, 30·5, Chattanooga.	Steep along coast.
" 6	Very marked, 17μ....	About constant, 759. .	Low, 29·4, Gulf; high, 30·4, Chattanooga.	Steep in Gulf.
" 7	Strong till midnight, 12μ.	About constant, 760... .	Low, 29·9, Gulf; high 30·3, Charleston.	Not steep.
" 13	Fairly quiescent till 6 p.m., then increase by 6 a.m., to 12μ.	Nearly constant, 764, with many fluctuations of 1 mm.	Low, 29·6, Gulf; high, 30·3, Washington.	Steeper, Lower St. Lawrence.
" 17	Fairly strong, 13μ. .	Nearly constant, 757	Low, 29·5, off Sable Island; high, 30·2, Charleston.	Not steep.
" 24	Fairly strong, 11μ. ..	Rises rapidly, 13 mm. to 755.	Low, 28·7, mouth St. Lawrence; high, 30·2, Texas.	Very steep.
" 25	Fairly strong, 13μ ...	Falls to 751, then rapidly rises to 765.	Low, 29·5, Gulf; another, 29·5, N. Michigan; high, 30·2, Jacksonville.	Steep.
" 31	Strong, 17μ. .. .	Falls 4 mm., then nearly constant, 754.	Low, 28·9, Gulf; high, 30·3, Chattanooga.	Very steep.
1908.				
Jan. 1	Begins with strong, then diminish.	Gradually rises, 5 mm .	Low, 29·6, Gulf; high, 30·3, Charleston.	Not steep.
" 5	Strong, increase to midnight, 17μ.	Gradually falling to 754.	Low, 29·2, Gulf; high, 30·3, Chicago.	Very steep.
" 12	Fairly strong, 9μ ...	... .	Low, 29·2, Cincinnati; high, 30·2, Gulf.	Steep about low.
" 14	Increase to midnight, 8μ.	Rises 9 mm. to 761	Low, 29·2, Gulf; high, 30·3, Memphis.	Steep.
" 23	Marked.......... ...	Nearly constant, 763 ...	Low, 29·6, Gulf; high, 30·7, Omaha.	Steep, Lower St. Lawrence.
" 24	Strong, 15μ........ .	Rapidly falls, 17 mm. to 747.	Low, 29·5, off Hatteras; low, 29·6, Winnipeg; high, 30·3, Anticosti; high, 30·5, Memphis.	Very steep low to low.
" 25	Well marked, decreasing.	Rises to 753.....	Low, 29·1, Sable Island; high, 30·2, Jacksonville.	Steep about low.
" 27	Small, 8μ	Rises rapidly, 18 mm. to 754.	Low, 28·9, Quebec; high, 30·1, Memphis.	Extremely steep about low.
Feb. 1	Increase after 6 p.m., 11μ.	Falls 13 mm. to 732, then rises to 745.	Low, 29·1, Detroit; high, 30·4, Sable Island.	Extremely steep about low.
" 2	Strong, 13μ..	Gradually rises to 755. ..	Low, 28·9, mouth St. Lawrence; high, 30·6, Memphis.	Very steep.
" 15	Small, increasing, 9μ.	Falls 5 mm. to 730, then rises rapidly to 746.	Low, 29·0 Buffalo; high, 30·4, Salt Lake.	Steep about low.
" 16	Well marked, 11μ...	Slight rise	Low, 29·0, Anticosti; high, 30·3, Denver.	Steep about low.

Date.	Microseisms.	Barometer in mm.	High and Low areas.	Gradients.
1908.				
Feb. 20	Fairly strong, 10μ	Nearly constant, 754....	Low, 29·5, St. John; high, 30·5, Vicksburg.	Fairly steep.
" 21	Strong, 13μ........	Rises 3 mm. to 756.	Low, 29·4, St. Johns; high, 30·4, Montgomery.	Fairly steep.
22	Well marked, decreasing, 9μ.	Nearly constant, 754...	Low, 29·7, mouth St. Lawrence; high, 30·4, Galveston.	Fairly steep.
Mar. 6	Fairly strong, decrease after 10 p.m., 11μ.	Rapid fall, 18 mm. to 741 midnight, then rise to 749.	Low, 29·2, Wisconsin; high, 30·3, Boston.	Very steep.
" 10	Fairly strong, decreasing, 9μ.	Rapid fall, 18 mm., to 753	Low, 29·4, St. Johns; high, 30·7, Cincinnati.	Very steep in Gulf.
" 25	Marked, decrease after 7 p.m., 8μ.	Falling 15 mm., with many fluctuations to 751.	Low, 29·6, St. Johns; high, 30·3, Ottawa.	Fairly steep.
" 30	Small, 5μ............	Gradually falls, 10 mm., to 756.	Low, 29·5, off Sable Island; high, 30·4, Philadelphia.	Fairly steep.
" 31	Small, strongest during night.	Rises, 8 mm., to 764.	Low, 29·8, off St. Johns; another, 29·9, Detroit; high, 30·3 off Nantucket.	Fairly steep.

In connection with the relationship that may exist between microseisms on the one hand and the statical and dynamical conditions of the atmosphere on the other, the following table has been compiled. In it are given all the well-marked or strong microseisms and all the strong winds and gales predicted at 8 a.m. for the Ottawa and Upper St. Lawrence valleys for the respective day, including the period July 1, 1907, to March 31, 1908, so that at a glance we can see whether more or less strong microseisms were accompanied by strong winds or gales, and on the other hand whether strong or high winds produced marked microseisms. As the observatory is not yet supplied with an anemometer and pressure gauge for comparison of the dynamical conditions, we are at present dependent upon the daily forecast as given below:—

The maximum (double) absolute amplitude or range is expressed in microns.

Date.	Microseisms.	Forecast for day.
1907.		
July 2.	Quiescent	Strong northwesterly winds.
" 26.	Very slight	High " "
" 27.	" become more marked.	Strong westerly "
" 29.	Slight, increase to 8μ	Thunderstorms.
" 30.	Marked, decreasing 11μ	Westerly winds.
" 31.	Marked 13μ	" "
Aug. 2.	Quiescent	Fresh to strong southerly winds, shifting to west.
" 24.	"	Strong southerly winds, shifting to west and northwest.
" 31.	Marked 13μ	Light to moderate winds.
Sep. 12.	Very faintest.	Fresh to strong west to northwest.
" 13.	"Sawtooth" type	Light to moderate winds.
" 14.	Well marked.	" "
" 18.	"	Fresh to strong northeasterly to easterly winds.
" 19.	" 8μ	Easterly to southerly winds.
" 20	Present, not as strong as yesterday.	Winds increasing to strong breezes and gales S. to W.
" 24.	Small	Strong winds and gales south, shifting to W. and N. W.
" 25.	Slight	Strong winds and gales west to northwest.
" 28.	Very minute.	Strong winds and gales east to northeast.
" 30.	Very strong, 25μ	Fresh to strong west to northwesterly winds.
Oct. 1.	Well-marked, 12μ	No forecast for winds.
" 2.	"	" "
" 3.	" 15μ	" "
" 4.	" 9μ	Fresh to strong northwesterly to westerly winds.
" 7.	" 13μ	Fresh winds.
" 8.	Small	Northwesterly gales.
" 9.	Well-marked 13μ	Showery, high winds to-night.
" 16.	Slight, increase to 16μ	Southwesterly winds.
" 17.	Slight	" " increasing to gales.
" 18.	" , increase to 7μ	Strong northwesterly winds.
" 19.	" " 10μ	Moderate winds.
" 20.	Well-marked 12μ	
" 21.	Strong 21μ	Moderate westerly winds.
" 22.	Very strong 25μ	Strong southwesterly winds.
" 23.	" 21μ	" northwesterly winds.
" 24.	Fairly strong 11μ	Westerly and southwesterly winds.
" 25.	Strong 17μ	Strong westerly and northwesterly winds.
" 26.	Fairly strong 12μ	Moderate winds.
" 27.	Well-marked 8μ	
" 29.	Fairly strong 14μ	Strong northerly winds.
" 30.	" 12μ	Northerly winds.
" 31.	Well-marked 9μ	No chart.
Nov. 4.	Slight, increase to 16μ	Westerly winds.
" 6.	Slight, increase after 5 p.m. to 9 a.m. 21μ	Northeasterly winds.
" 7.	Strong 18μ	Northwesterly and westerly gales.
" 8.	Fairly strong 10μ	Strong westerly winds.
" 9	Marked 8μ	High southwesterly winds.
" 21.	Small, very weak	" south and southwesterly winds.
" 25.	Very marked 17μ	Northeasterly winds.
" 29.	Very strong 25μ	Strong northerly winds.
" 30.	Marked 14μ	Easterly winds.
Dec. 2.	" 17μ	Fresh northerly to westerly winds.
" 5.	Becoming very strong 21μ	Westerly winds.
" 6.	Very marked 17μ	Moderate to fresh southerly to southwesterly winds.
" 7.	Strong till midnight 12μ	Moderate southwesterly to southerly winds.
" 9.	Almost quiescent	Winds increasing to strong breezes, gales E. and S.
" 10.	Very slight	Strong winds and gales W. to N.
" 11.	"	Fresh to strong northerly to northwesterly winds.
" 13.	Fairly quiescent till 6 p.m., then increase by 6 a.m. to 12μ	No forecast for wind.
" 14.	Less strong than yesterday	Northeasterly to northerly gales.
" 17.	Fairly strong	No forecast for wind.
" 20.	Slight	Fresh to strong southerly winds.
" 23.	Not strong	Strong winds.
" 24.	Fairly strong 11μ	No forecast for wind.
" 25.	" 13μ	" "

Date.	Microseisms.	Forecast for day.
1907.		
Dec. 27.	Not strong	Strong southerly and southwesterly winds.
" 30.	Small	Strong winds and gales shifting to W. and N.W.
" 31.	Strong 17μ	Fresh to strong westerly to southwesterly winds.
1908.		
Jan. 1.	Begin strong and then diminish.	No forecast for wind.
" 4.	Almost quiescent.	Strong southwesterly winds.
" 5.	Strong, increase to midnight 17μ	No forecast for wind.
" 12.	Fairly strong 9μ	" "
" 14.	Increase to midnight 8μ	Westerly winds.
" 15.	Weak	Strong winds.
" 16.	Slight	Strong northwesterly winds.
" 22.	"	High " "
" 23.	Marked	Northerly winds, decidedly cold.
" 24.	Strong 15μ	No forecast for wind.
" 25.	Well-marked, decreasing.	" "
" 27.	Small 8μ	Strong westerly to northwesterly winds.
Feb. 1.	Increase after 6 p.m. 11μ	Strong winds and gales eastern quadrant, shifting to W. and N. W.
" 2	Strong 13μ	No forecast for wind.
" 5.	Practically none	Strong winds and gales, E. to S.
" 6.	Weak	" " shifting to W. and N.
" 15.	Small, increasing 9μ	Strong winds and gales, N.E. to N.W.
" 16.	Well-marked 11μ	No forecast for wind.
" 19	Very minute	Strong easterly to northeasterly winds.
" 20.	Fairly strong 10μ	Fresh northwesterly to southwesterly winds.
" 21.	Strong 13μ	Fresh to strong southwesterly to westerly winds.
" 22.	Well-marked, decreasing 9μ	No forecast for wind.
" 25.	Practically none	Fresh to strong winds.
" 26.	Very minute.	Strong winds, shifting to N. and N.W.
Mar. 2.	Very slight	Strong northeasterly winds.
" 6.	Fairly strong, decrease after 6 p.m. 11μ	High southeasterly winds.
" 10.	Fairly strong, decreasing 9μ	Moderate westerly winds.
" 11.	Slight	Fresh to strong southwesterly winds.
" 13.	Very slight	Strong southerly winds.
" 16.	Practically none	Strong northwesterly winds.
" 24.	Small	" "
" 25.	Marked	No forecast for winds.
" 26	Small	Strong northwesterly winds.

It may be stated at the outset before discussing the preceding data that there is never a day in the year on which some trace of microseisms can not be seen on a seismogram from a Bosch photographic seismograph. It is all a matter of degree. That microseisms should be ever present is but natural, for the earth is in a continual state of stress and strain; many varied and different causes contributing thereto. The term microseisms as here used excludes any deviations of the vertical or movements of the zero position of the pendulum. Some writers have divided microseisms into 'earth tremors' or 'pulsations,' and 'earth pulsations' or 'pulsatory oscillations.' The writer, however, from the seismograms at this station sees no reason for this division, as it is not at all evident from them that the contributory causes, whatever they may be, manifest themselves in such a manner as clearly to differentiate themselves. Furthermore, from the examination of the seismograms the oscillations of the pendulum are excluded, on the one hand, from the frequent change of period on the same seismogram, which would be inadmissible for a pendulum, and on the other hand, if the pendulum were made to oscillate we should expect to see the damping effect in the decrease of amplitude, and a more or less sudden beginning, unless the oscillations of the earth particles them-

selves were of a period commensurable with that of the pendulum, which, of course, is sometimes the case. It is evident that a photographic registering apparatus with high magnification will record microseisms when a seismograph with mechanical registration will draw only a straight line.

Of the contributory causes to stresses and strains and manifesting themselves as microseisms, we may consider: secular cooling of the earth; unequal heating and radiation during the day and night; statical effect of atmospheric pressure, areal or local; dynamical effect of atmospheric pressure, areal or local; precipitation, as rain or snow.

The vanishingly small effect of secular cooling, whatever its constants may be, becomes evident from the fact, that although it is ever present and its manifestations would be of a constant nature, the recorded microseisms are of the most fluctuating character both in time and magnitude, completely masking the effect of secular cooling. The daily alternations of unequal heating and radiation during the 24 hours are not shown by their effect on microseisms. The case of precipitation is similar in regard to microseisms to the preceding. It may be noted that the stresses set up over large areas, hundreds of miles in extent, by differential loading of rain is small compared with that of barometric pressure. Taking an area say of a 1,000 miles with a rain-fall of an inch, which is a pretty heavy rain, and decreasingly distributed, we would have a maximum pressure of a little over one thirtieth of a pound per square inch, and the rain pressure diminishing to zero for the edge of the area. An average barometric gradient, on the other hand, over such an area would be several times as great, due to a differential atmospheric pressure equivalent to about three-tenths of an inch of the mercurial barometer. The rain-pressure may make itself, however, felt locally, as has been observed. The result of a heavy rain-fall soon fills the valleys and streams much beyond the direct precipitation on them, so that this loading and bending of the surface may become a measurable quantity by an observing station in the neighbourhood. This effect is, however, one of tilting, of change of vertical or change of pendulum zero and not of microseisms, the subject at the moment under discussion

The effect of difference of atmospheric pressure and of change of atmospheric pressure may be manifested in two ways by the seismograph. We are here dealing with large areas, say 1,000 miles in extent, for local barometric conditions have little or nothing in common with microseisms. In the one case, considering the earth as having an elastic crust, the pier is tilted towards the area of greatest pressure, in consequence of which the pendulum will move in that direction, i.e., its zero line will be displaced. Besides this effect of statical loading, there appears to be no doubt, based on the records here, that vibrations are set up by this statical loading, quite apart from the dynamical effect of change of pressure. In the other case, by change of pressure over a wide area vibrations are set up on the earth's surface, and these may be produced by two causes from the one phenomenon. The one of these is the passage of Highs and Lows over the surface, equivalent to the dragging of a weighted meniscus over the surface; and the other is the winds set up or resulting from the atmospheric gradient due to difference of pressure. The action of the winds would be most likely from frictional resistance along the surface of the earth rather than from impact on unevenness of surface or obstructions. In studying various phenomena collectively in an investigation for co-relationship, considerable restraint must be exercised not to draw conclusions as to cause and effect from a limited number of coincidences. For a conclusion once drawn is apt to become an obsession to the investigator, and he is more or less blinded to facts that do not fit his theory.

In examining the record of microseisms the first question that presents itself is whether the recorded motion is that of the ground or of the pendulum, in the first case the pendulum acts as a steady mass or point, while in the latter case it is set oscillating either by impulses from the ground or by an undulatory movement of the ground. Let us consider the case of microseismic records of the 'sawtooth' type, where we see

regular and almost wholly uniform oscillations kept up for hours and longer. If in this case the pendulum actually oscillates it will do so with the period inherent to it. After receiving the first impulse or impact let us suppose it to oscillate, if no further impact were received the oscillations would soon die out and the amplitudes would decrease in the given ratio of the damping co-efficient. When a second impulse is given the pendulum will continue its uniform swings, provided the time interval from the preceding impulse is that of the period of the pendulum or a multiple thereof. Is this not the case, then we will have interference and this would be shown on the record. But such interference is not present in our supposed diagram, hence we must conclude that even if we admit that the diagram is a record of the oscillations of the pendulum, we see that in reality it is only a counterpart of the actual movements of the ground, that is of horizontal to and fro motions of the earth particles. If the pendulum is kept swinging uniformly it can only be done so by some force acting at intervals of the period of the pendulum. As indicated, this may be done by the periodic oscillating movements of the earth particles; or the same effect may be produced by rhythmic undulatory movements of the ground. Now, the period of microseisms recorded here lies mostly between 5 and 6 seconds, which it may be remarked is also approximately the period of the two pendulums, and the period of the undulatory movements manifested in the 'principal portion' of tectonic earthquakes is 20 seconds or more, so that for microseisms we find the period only about one-quarter of the preceding, provided we admit that the record of the microseisms is due to undulatory motion and not to horizontal movements. The shorter period might perhaps be assigned to a far thinner part of the crust of the earth being affected in the microseisms than is involved in the undulatory motion connected with microseisms. As an analogy we may give the short period of the ripples in water from a breeze, or the much longer one of waves from a storm when a greater depth of water is involved in the motion.

A priori reasoning does not appear to furnish a conclusive reply to the question whether the microseisms are attributable to the horizontal or to the undulatory movements. However, from the consideration of the simultaneous occurrence of microseisms together with certain atmospheric or barometric conditions lead to the conclusion that microseisms are mostly attributable to horizontal displacements.

Having made daily comparisons with the seismograms, local barograms and weather maps, the following conclusions have been deduced. It is believed that identical atmospheric conditions prevailing over different parts of the earth's surface will not necessarily produce similar microseisms as these are affected by the elasticity of the particular area under consideration, also by the geological formation, the presence of well-marked dykes and faults, and by the proximity of large sheets of water, the ocean. One effect of the proximity of the ocean caused by barometric pressure is the change of the level of the water, quite apart from the tides, and this change through loading or unloading along the coast produces a displacement of the pendulum zero, referred to in another place. In the sea then, we have the dual effect of the direct barometric pressure and the correlated one of displacement of the water, while on land we have only the former.

The feature to strike one most in the above comparisons is that when marked microseisms are present we are almost certain to find in the morning of the day of record for the following 24 hours an area of Low about the Gulf of St. Lawrence. That is, the condition of Low in the gulf precedes the record of marked microseisms. The greater part of the gulf is less than 150 fathoms deep. Through it runs a deep from the mouth of the St. Lawrence (Matane), along the south of Anticosti, passing between Cape Breton and Newfoundland reaching a depth of 250 fathoms before joining the Atlantic ocean. This deep is over the eastern part of the Great St. Lawrence and Champlain Fault, shown on the geological maps, for nearly 700 miles. The waters about Nova Scotia and Newfoundland are all within the 150-fathom line, so that the Lows over the gulf and Sable island are over waters the greater part of

which is less than 150 fathoms deep. The distance from Ottawa to the gulf is about 700 miles, direction east-north-east; and from Ottawa to the nearest broad waters of the Atlantic, off the State of Maine, 300 miles, direction east-south-east.

Next to the presence of a Low in the gulf co-incident with microseisms we find the isobars to cut the valley of the St. Lawrence (in which lies the great fault) at right angles, that is, the gradient is along the St. Lawrence valley, which is in general parallel to the Atlantic coast, and to the line of the Alleghany mountains.

Furthermore, it is found that if a High prevails along the South Atlantic coast, northward from Florida the microseisms are intensified.

The passing of Highs or Lows across the coast-line, i.e., from land to water is not found to be marked by the occurrence of microseisms. As the whole atmospheric movement is for Canada and the United States from west to east, it is uncommon for a High or Low to cross the coast line from the Atlantic to the continent.

It appears that the reversal of the position of Low and High with reference to the gulf for the former is not so closely associated with the subsequent appearance of microseisms as obtains in the case first stated.

When there is a persistence of Low in the gulf and High on the Atlantic coast to the south as indicated, the microseisms set up in the first instance become intensified in amplitude, so that the maximum microseisms are not necessarily co-incident with the greatest difference of pressure. It appears that the difference of barometric pressure is in the first instance responsible for the microseisms, and when favourable conditions continue the microseisms will increase in amplitude, although the pressure difference may have decreased. Furthermore, another condition is that the line of High-Low preserves its direction along the St. Lawrence valley.

When a Low with even very steep gradients is to the west, say over the lakes, and High over the Lower St. Lawrence or gulf, microseisms are generally weak or even absent altogether, although there are exceptions. This is not the case when the Low is to the east, especially when over the gulf. When the Low with steep gradients moves up to Lake Erie by 8 a.m. of the day of the seismogram we may expect to see the beginning of marked microseisms, which increase as the Low moves down the St. Lawrence towards the gulf. From the immediately preceding it is seen that the microseisms give no indication of the approach of a Low or storm centre, but on the contrary are the result of the passage of a Low, and especially of its presence in the gulf. Some investigators believe and are in hope the microseisms may be the forerunner of coming weather conditions, and hence may assist in making forecasts. The seismograms examined here are not very encouraging on that point, the microseisms indicating rather 'that we have had weather, than that we are going to have weather.' This prognostication refers to the microseisms and not to the effect of bending, or displacement of the pendulum zero, brought about by unequal pressure over a large area. The writer is not as yet prepared to say whether the approach of a Low, with the consequent lifting or rising of the earth's surface, is a distinctly measurable quantity as registered by our seismograph, for the measurements of the two components of the change of pendulum zero for the year have not yet been tabulated and critically compared with the movements of Highs and Lows in the eastern part of the continent.

In connection with the bending of the earth's crust due to difference of atmospheric pressure, reference may be made to two exceptionally marked results obtained by Professor Omori. The conditions prevailing were undoubtedly unusual, and the angular values obtained so large, that one would be led to conclude that under ordinary atmospheric conditions, i.e., of barometric difference, the tiltometer would always respond to a degree that was readily measurable. Of this fact, however, the text, in the references given below, says nothing.

In No. 21 of the Publications of the Earthquake Investigation Committee in Foreign Languages is given the record, with its interpretation, of a horizontal

pendulum at Tokyo during a storm, October 10-11, 1904. The weather chart which accompanies the paper shows that a Low (750mm) prevailed and moved along the east coast of Japan past Tokyo. This Low had a gradient for Tokyo of 10mm in about 220km. This is an excessively steep gradient. Elsewhere it has already been stated that a gradient of one-tenth inch for 150 miles is a pretty steep gradient; it will be seen then that the former is fully four times as great as the latter. The tilting diagram shows the movement of the Low very well, and from the constants of the pendulum, the angular motion or tilting, is found to be 3″·5, a very large quantity. As the Low was east of Tokyo, the natural inference would be that the pendulum would swing to the west towards the High, which depresses the surface of the earth, but the opposite was found to be the case. On this interesting and important point Omori says: 'The explanation of this apparently anomalous phenomenon is probably to be found in the accumulation of sea waters under the low pressure centre to a degree greater than the amount of the diminution of the atmospheric pressure, thereby creating an increase in the resultant pressure at sea bottom.'

In interpreting the above phenomenon it seems necessary to consider the effect of the hydrographic features and coast line, for statically considered the difference of barometric pressure over the ocean raises the water under low pressure to a height equal to the difference between the High and Low, to produce hydrostatic equilibrium. However, when the Low is along or near the coast and the waters from the ocean flow from the High towards the Low, then there may be and probably is a piling up of waters along the coast due to configuration, which would not be the case on the broad ocean.

In the comments on Mr. Denison's paper, the dual effect of difference of atmospheric pressure over the ocean has been pointed out, and Professor Omori's observations show it so glaringly.

The other case is the record obtained at Mito (Japan) during a storm 22-24 March, 1907, given in 'Bulletin of the Imperial Earthquake Investigation Committee,' Vol. II., No. 1. The atmospheric conditions were similar but not identical. The gradient in this case was 10mm in about 400km, and furthermore two Lows moved simultaneously northeasterly along the Japanese islands, one on each side, thereby materially changing the direction of the gradient and of the direction of tilting as well as of its progressive movement. From the constants given, the instrument used seems to have been identical with the one used at Tokyo. The tilting recorded at Mito was 3″·7, a little higher than at Tokyo, although the atmospheric conditions were seemingly somewhat less favourable. An additional record of interest in this case is the mareogram for the time of the storm. From it is seen that the effect of the Low is to raise the water 75cm or two and a half feet 'higher than the level according to the usual tide movement.' The direction of the tilting with reference to the position of the Low was similar to the case of Tokyo; Omori saying: 'The passage of the centre of the cyclone producing, as in the case of the storm on October 10-11, 1904, not an elevation but the depression of the ground. This is probably due to the fact that the deep barometric cyclone was accompanied, or rather followed, by an increase of the height of sea water, to an amount greater than the equivalent of the barometric fall.'

We see then from these two cited cases that the secondary effect of difference of atmospheric pressure for coastal stations may completely mask, in fact reverse, the direct pressure effect upon the earth's surface produced by an atmospheric gradient. These cases seem to make it clear that the direct gravity effect produced by the cumulating waters is very much greater than that of the difference of atmospheric pressure, and is of opposite sign.

It is found that, broadly speaking, the microseisms are more numerous during the colder season than during the warmer one, and some have sought therein a relationship of cause and effect. In our climate here we have a large range of temperature; during

the past year of 127° F. (96° and —31°). During February when the thermometer reached its lowest and we had some continuously very cold weather the seismograph showed no evidence thereof. The connection is assumed to be from the fact that the frozen ground on the one hand lends itself for the better transmission of pulsations, and the other that the act of freezing itself sets up stresses and consequent oscillations that manifest themselves as microseisms. From extreme cold it does not necessarily follow that the ground is frozen to any great depth, as was the case during the past winter. The reason that there was very little frost in the ground, was that an early and heavy snowfall together with its subsequent accumulation to many feet, covered the earth with a mantle that the cold could not penetrate.

By far the large majority of microseisms show themselves by a serrated record, 'sawtooth' type as I designate them; more rarely are those of the 'spindle' type, where the oscillations or rather the amplitudes rise and fall, increase and decrease, with a certain cadence, as in the oscillations of a string between two fixed points. The interval between these maximum amplitudes is very variable, varying from one to several minutes. The rate of increase and decrease of the amplitudes is less than that produced by the damping of the pendulum, so that we can scarcely attribute it to the latter on the supposition that the pendulum itself is set in motion and the oscillation dies down by damping, the former to be renewed by a fresh impulse. The latter, however, would preclude a gentle increase, but instead would show a more or less abrupt beginning, which is not the case. Intermittent rhythmic vibrations of the ground, synchronizing with the period of the pendulum, setting the pendulum in motion could produce the phenomenon. Other suggestions might be made, but none seems satisfactory to explain the more or less rhythmic fluctuations in amplitude as shown on Plate 1.

The validity of a supposed relationship between different phenomena, as cause and effect, is readily tried by predicting the effect when given the cause. This has been done with reference to the existence of a Low in the gulf and a High over the Atlantic coast to the south, or in general by taking the daily Weather Map with its isobars and from them predicting the resulting microseisms. The result has in so far been satisfactory that in the large majority of cases the microseisms have fairly well answered in presence and magnitude the prediction. There are, however, still important outstanding differences that require further explanation. Just why the Low about the gulf should have such an influence in the production of microseisms is by no means apparent. The two main physical features are the shallow gulf and the St. Lawrence valley in which lies the Great St. Lawrence and Champlain Fault 700 miles long, already referred to. As secondary, is the general trend of the Atlantic coast, and possibly that too of the Alleghany mountains.

On infrequent occasions there is a Low over the gulf, another Low over Arkansas, while one High rests north of Lake Superior and another over Bermuda. When those conditions obtain with steep gradients we are pretty sure to have marked microseisms. The line of the Lows then lies in the St. Lawrence valley, while that of the Highs is at right angles to the former. In this case the maximum strain is along the valley of the St. Lawrence, along the Great Fault, so that from a priori reasoning marked microseisms might be expected.

In concluding this preliminary investigation of the well-marked microseisms recorded here, we will repeat that the presence of a Low over the gulf surrounded by steep or fairly steep gradients on a given morning is indicative of more or less well-marked microseisms following at Ottawa that day.

It has already been stated that the large majority of microseisms have a period of about 6^s with small fluctuations. Why the fluctuations, is by no means apparent, unless it be the varying depth of the earth's surface involved. Even this supposition is not quite satisfactory; for all impulses, vibrations of whatsoever nature must pass

through the pier on which the instrument rests before being recorded, and the pier itself must have its own inherent and constant period.

On occasions the above common period changes to one of about one-half, or about 3^s, showing, however, a transition time during which there is an irregularity and interference, so that the period is unrecognizable. At present no explanation can be offered for this sudden change. When the period is so short, the amplitudes are very minute, although visible to the naked eye.

From the preceding tabulation it will be observed that the strongest and most numerous micr seisms were recorded during the month of October, and the fewest and weakest during the summer months of July and August when the atmospheric barometric gradients were very long. Coming now to the next table in which the days for all the well-marked microseisms and for all the strong winds forecast are given, we find that of these 100 days between July 1, 1907, and March 31, 1908, there were only 15 coincidences of such microseisms and such winds. It must be remembered, as already noted, that the winds are those of the forecasts and not recorded ones, as at present the observatory is not provided with the necessary meteorological instruments. However, the probability of the forecasts is and has been high for years.

On these data and conditions we are led to infer that strong winds have little effect in causing microseisms by setting up pulsations over large areas of the earth's surface or crust, i.e., the dynamical effect by friction or impact is not the governing factor in the production of microseisms. We are dealing here with the larger effect of strong winds upon large areas and not the local effect upon buildings, which as is well known are set in oscillation, and these in turn are communicated to the ground. When the building within which the seismograph is housed is large, the oscillations of the former will be recorded.

We have in the period, July 2—March 26, one hundred days during which 51 marked or well-marked microseisms are recorded, and 36 strong winds are predicted. Considering the two phenomena as independent events we see that the probability of the simultaneous occurrence of the two events is as great as the actual happening, i.e., as far as the observations go there is very little to show any causal relationship between the two.

I attended the first general meeting of the International Seismological Association and the second meeting of the Permanent Commission held at the Hague, September 21—September 26, 1907.

There are now 21 countries—Austria, Belgium, Bulgaria, Canada, Chile, Congo States, Great Britain, Greece, Hungary, Italy, Japan, Mexico, Netherlands, Norway, Portugal, Roumania, Russia, Servia, Spain, Switzerland and the United States—represented in the association. The meeting took place under the patronage of the government of the Netherlands and many courtesies were extended that were highly appreciated by the members. There were some fifty seismologists, including the leading seismologists of the world, who attended the conference. The meetings were to have been held in the Ritterzaal, but as those quarters were still occupied by the Peace Conference, the government assigned the Diligentia for the conference. Professor Van der Stok, vice-president of the association, and his assistants made all the arrangements, and they were indefatigable in their endeavours to make the visit of the members as pleasant as possible, in which they were highly successful. A cloudless sky during the whole session added not a little to the enjoyment.

The meetings opened by a two days session of the permanent commission under the presidency of Professor Luigi Palazzo, Director of the Central Meteorological and Geodynamic Bureau at Rome, who delivered his presidential address in French. During the session the usual routine business pertaining to reports and finances of the association was disposed of.

It has long been felt that there should be a material increase in the number of seismological recording stations and to this end a cheap yet suitable and satisfactory

instrument was desired. To secure the latter, instrument makers had been invited to submit working apparatus and the cost was limited to 300 marks, about 75 dollars. This limit was subsequently considered, and rightly so, too low. A number of instruments were submitted for examination, and a committee was appointed, including the writer, to report on their efficiency. The committee, however, on due examination and deliberation recommended that a satisfactory test could only be made by setting up the instruments at a station and let them do actual work, recording seisms of various kinds, for a considerable length of time before a conclusive report could be made as to their suitability. This recommendation was adopted and the instruments will be set up at the Central Bureau at Strassburg under the supervision of Director Gerland and Professor Rudolph.

The association being a new organization, its work is not yet differentiated and so ordered as obtains in older societies. At the present time there are two points particularly, that strike the writer as being important for the study of earthquakes and the geophysical questions involved, which should receive immediate attention. The first point is, and one involving little expense, if any, that the Central Bureau at Strassburg should through the press publish in brief the occurrence of every large (tectonic) earthquake. If the reading and interpretation of a seismogram were as simple and easy as that of a chronograph sheet for transits, then there would be little object for the above desired information. Such, however, not being the case, the reading of a seismogram can very often only be effected satisfactorily by comparison with another or others. Earth tremors or microseisms sometimes mask the arrival of the first preliminary tremors so that not even an approximate estimate can be made of the distance to the epicentre or disturbed area. The first question that presents itself to the reader of the seismogram as well as to the public is, where was the earthquake? The answer to this question would be materially enhanced in value were the information referred to made available. It may be noted too that each comparison between the record of the Central Bureau and one's own will assist towards the independent reading or interpretation of every following seismogram.

The other point involves some expense, no doubt. It pertains to the rapid reproduction and distribution of seismograms from stations where efficient seismographs are installed and above all, where a very accurate time scale is recorded. This last condition is absolutely essential if the seismogram is to be of any use in studying the geophysical problems involved in an earthquake record. It is almost futile to attempt the solution of the many seismic questions presented by the study of one's own seismogram only. We have the same phenomenon, waves of different kinds supposedly, emanating from the same source, sending their pulsations along paths yet not well known, to every part of the earth to be recorded, and now the problem becomes to trace these pulsations, tell us their nature, the medium or mediums through which they have passed, and their properly differentiated velocities. The most expeditious method would seem to be that those stations which are provided with efficient seismographs and with an accurate time scale immediately interchange copies of the record of a tectonic earthquake also giving the instrumental constants involved. The reproduction of the seismograms of the various stations by the Central Bureau, as was done for the Valparaiso and North Pacific quakes, is rather expensive and involves too much time. Only by such means can we hope to successfully attack the problems of seismology.

The general meeting was opened on Tuesday by His Excellency, Mr. Fock, the Minister of Colonies, who in the name of Queen Wilhelmina extended a welcome to the members. After a suitable reply by the president, the meeting proceeded to business, and continued in session for the following two days. German and French were the prevailing languages at the meetings; Professor Omori of Japan and the writer were the only ones to address the congress in English.

The following is a list of the papers presented:—

Lagrange.—A propos des Mistpoeffers de la mer du Nord.

Rosenthal.—Sur le catalogue microséismique de l'année 1904.

Rudolph.—Comment faut-il analyser les sismogrammes?

Oddone.—Discussion statistique du grand catalogue des tremblements de terre connu, survenus dans l'année 1904.

Rudolph.—Sur la publication de sismogrammes du 16-17 août 1906.

Mainka.—Über die neueren Arbeiten im Strassburger Observatorium.

Lagrange.—Mouvement élastiques du sol de la station de Quenast.

Goultieff.—Présentations des sismogrammes.

Prince B. Galitzin.—Seismometrische Studien.

J. Mihailowitsch.—Über die Organisation des seismischen Dienstes in Serbien.

Rosenthal—Remarques sur la propagation des ondes sismiques longues.

Agamennone.—L'eau, cause indirecte des tremblements de terre.

Omori.—On San Francisco, Formosa & Indian earthquakes.

Wiechert.—Die Verwendungen der Erdbebenregistrierungen zur Bestimmung der Beschaffenheit des Erdinnern.

The important question of cataloguing earthquakes, after some discussion was referred to a committee to report thereon. The question may be viewed from different standpoints, and the conclusions arrived at will accordingly differ. To the geophysicist who is particularly interested in the propagation and nature of seismic waves as dependent upon the interior of the earth, it is essential that all the tectonic or world-shaking earthquakes be tabulated for the principal or all the observing stations in the world, giving the data—first preliminary tremors; second preliminary tremors; principal portion; and duration—similar to those given under 'Liste A, Hauptbeben,' in the catalogue of the registered seismic disturbances for the year 1904, and issued by the International Seismological Association. With such data at hand each investigator can utilize them independently. The occurrence or registration of minor or local quakes are of little, or at least less, importance to him. It seems, therefore, highly desirable that these severe earthquakes be catalogued, and chronologically.

For studying the seismicity of the earth's surface, which would include the record of all felt earthquakes, the regional collation of the seisms represented graphically, somewhat on the lines of Montessus' 'Tremblements de Terre,' would probably give one a better grasp of the subject than a numerical tabulation chronological or regional. The graphic representation has the advantage too that in the chart or map the orographic features may be shown, and the relationship between the former and latter established or indicated.

The new science of seismology is developing so rapidly that it is desirable to publish annually a bibliography on the subject, and a committee with that end in view was appointed.

The conference was closed by the government providing a visit to the observatory at Leyden and an excursion over the network of canals. To many the most interesting part of the well-equipped observatory is its historical exhibit,—the clock, the quadrant, the mural circle and other instruments of the great Huyghens. The clock is still kept going, being one of the first pendulum clocks constructed, as Huyghens was the first to apply the pendulum to clocks (1656), although Galileo had anticipated (1641) the idea. It is provided with cycloidal cheeks, a theoretical consideration for isochronoism, but now abandoned in clocks.

The chartered steamer for the round trip to Braasemer Meer was in holiday attire. The greater part of the district passed over is some seven metres (23 feet) beneath the level of the sea; and the canal on which we were, was considerably higher than the meadows adjoining, on which the black and white cattle were grazing. The Braasemer Meer is the remains of the former Haarlemer Meer which has been reclaimed by pumping.

The net result of this conference, in fact of any conference of scientific men, is not the reading of scientific papers, for as a rule there is no time for their discussion, and this is or would be the important feature, but in the personal contact and acquaintance of men labouring in the same field. One learns to appreciate more the work of others, and besides obtains a proper perspective of his own endeavours. As a matter of fact there is probably more benefit derived outside of the regular meetings, than at the sessions. At luncheons, at dinners, at social gatherings in the evening,—at such occasions questions are discussed, points elucidated, and information riveted that no reading or a formal address can give. The manifestation was general that the first meeting of the International Seismological Association was an undoubted success and augured well for the future.

After leaving the Hague various scientific institutions and observatories were visited, and much valuable information was gathered in the various branches or fields of our own work.

The first place visited was the earthquake station at Hamburg. The building with its splendid equipment, the time-service being particularly complete, is due to the generosity of a private citizen and scientist, Dr R. Schütt. To be noted first is that beneath the two instrument rooms are two massive concrete blocks about 26 × 11 feet, and 6½ feet deep, the bottom thereof being 22 feet beneath the surface and resting on marl. A 12-inch air-space separates the blocks from the walls of the building, and the top of the blocks is some four feet beneath the floor of the instrument room. The merit of the blocks is the greater stability, as well as the convenience of requiring to build only small piers resting on it for any other instruments that may be installed at a future time; otherwise it would be necessary to tear up the floor for getting the necessary foundation. This idea of having large cement blocks, deeply imbedded, as a huge pillar on which many small piers may be erected, I found applied at other institutions, and the writer considers it a very advantageous arrangement.

The earthquake equipment consists essentially of a Wiechert astatic 1,000 kilogram pendulum seismometer with two components, air damping and 200 magnification, and of a Hecker horizontal pendulum. The time service was installed according to the design of Riefler of Munich. From the depth of the foundations and piers, together with lack of proper drainage at that depth there is an accumulation of moisture which in spite of the free use of chloride of lime, ranges between 70 to 80 per cent, that is, the relative humidity is that amount. This circumstance seems rather common from my observation at earthquake stations. Weekly and monthly bulletins are issued by this station. This efficient and complete institution is solely for earthquakes and is not an appendage to a larger one.

The next place visited was the Geodetic Institute at Potsdam, where I discussed gravity work with Prof. Helmert and Dr. Borass, the former expressed the desirability of Canada carrying a series of pendulum observations across the continent from Newfoundland to the Pacific. Their new pendulum apparatus (half-seconds) is a frame carrying four pendulums, the object being to have them at the same temperature, and the chamber which can be kept under constant pressure need not be opened till the four observations have been made, and then reversal made. By means of mirrors and prisms all four can be made to give an image in the flash apparatus with which the coincidences are noted similar to ours. The pendulums are at right angles to each other. The observations are made with a pendulum clock (used in field work) for flashing, and which serves too for the necessary time observations. Helmert considers chronometers inferior for pendulum work, and said that if observations of only an hour's duration for a swing are made, as theirs are, then the pendulum clock should be used. However, for observations of eight hour's duration the chronometers are satisfactory.

The apparatus for gravity work on the high seas, as carried out by Professor Hecker between Lisbon and Rio Janerio and in the Pacific, was shown and explained.

It had long been recognized that theoretically it was possible to determine gravity at sea by the comparison of simultaneous readings of the mercurial barometer and of the temperature of boiling water. In the first case the atmospheric pressure is measured by the weight of the mercurial column of the barometer, which is generally expressed in height instead of by its weight. The observed height is not a true measure of the pressure, because it changes with the temperature of the mercury and with the variations in the value of gravity; this latter is the important feature here to be noted. In the second we have water heated in the free air, the elastic force of its vapour gradually increases, until it becomes equal to the overlying pressure of the atmosphere. Then, the pressure of the atmosphere being overcome, the steam escapes rapidly in large bubbles and the water boils. Thus the temperature at which water boils becomes a measure of the pressure of the atmospheric column above it.

The difficulty in the application of these methods hitherto has been the accurate reading of the barometer at sea and the vicissitudes attendant upon the determination of the boiling point. This has in so far been overcome as to render fairly good and accordant results, in giving some definite information over areas where before only surmises prevailed. For the barometric determination five barometers are suspended in a case hung in gimbals and carrying the whole apparatus for recording. To minimize the effect of 'pumping' at sea, the middle of the barometer tube is very contracted. A single small lamp by means of mirrors throws the shadow of the mercury column on a photographic sheet wound on a small cylinder operated by clock-work; on the sheet too is recorded by a clock with electric circuit, a time scale. The barometers are thus self-registering, and the barogram is a serrated line, still due to some pumping. For measurement the mean is taken of these serrations for the time corresponding to the 'boiling' of the thermometers. These latter are read visually to one thousandths of a degree centigrade, the graduations being to hundredths. I was informed that the accuracy of a gravity determination by this method is about one-tenth that by pendulum (on land).

A horizontal pendulum seismograph, Hecker design, is installed too. In connection herewith an interesting statement was made by Helmert, that with such a pendulum at a depth of some 20 metres beneath the surface the effect of the attraction of the moon as well as of the sun was observed, the quantity being about two-thirds of the theoretical value, the other third being lost in the tide of the earth's crust itself.

My next investigation was with reference to the means of measuring base lines. This is effected by an invar wire (not tape) 1·8mm diameter, and 24 metres long, made by Guilliaume (or Charpentier) in Paris. The wire terminates at each end in a triangular piece of about 8cm length, and graduated on one edge, a continuation of the wire to millimetres which are read to tenths. The modus operandi of use is somewhat as follows: Along the base line say of 5 kilometres, pegs (about 2½ inches square) are driven in alignment at 24m, a nail driven in the head, and levels taken of the pegs. At the end of the base line, stone monuments with suitable marks are supposed to be placed. The measurements are made with the wire suspended over two tripods (each over a peg) and under a tension of 10 kilogramme weights, supported on two large tripods, one on each side of the other tripods. Experience shows that the readings, or rather the length of the wire between two tripods, will agree within two-tenths of a millimetre, and that base-lines can readily be measured with a probable error of a millionth of the length. The whole operation of setting up the tripods and taking measurements was carried out for me on the grounds, and I myself took readings and manipulated the tripods supporting the weights, to see with what ease the alignment can be made over the small hemispherical heads of the smaller tripods on which the scale of the wire rests. The method appealed to me for its ease and rapidity of execution. The measurement of a base-line can be made as rapidly as five men can set up (in advance) the tripods over the pegs. For temperature, little or no regard in handling, or exposure to sunshine or rain, is had, on account of the extremely small

co-efficient of expansion. However, the wire requires to be handled with care to prevent torsion or other deformation or damage, as it has its idiosyncrasies. It was noticed that when the wire was suspended and under the strain of 10 kgm., that the curve was not a true catenary, but was wavy, irregular however, as if bent. Guilliaume recommended in taking up the wire to allow it to assume its natural bent, which is to roll up like a spiral, and simply gather the coils. However, doing so, it was found that they become smaller and smaller, so that the wire is now wound on an aluminum drum, half a metre in diameter. About invar tapes, Helmert volunteered no opinion, simply as he said, because he had not used any.

A brief visit was paid too on the same grounds to the Magnetic and Meteorological Observatory, where particularly the meteorological instruments were examined. These are practically all provided with electrical apparatus for recording.

The following day was spent in a visit to Friedenau and Steglitz near Berlin at the workshops of Bamberg and Fuess, the former the maker of high-class surveying and geodetic instruments, the latter of a similar grade of meteorological instruments. Much valuable information was gathered at both establishments.

The next place visited was Göttingen, where the Geophysical Institute under the direction of Professor Wiechert was inspected. The prominence the director has obtained in earthquake investigations, makes Göttingen an important station. The earthquake building is built into the hillside, and over the outer entrance is the significant inscription 'Ferne Kunde bringt Dir der schwankende Fels, Deute die Zeichen.' Three seismographs were found installed, all of the Wiechert type, built by Spindler & Hoyer. One is a 1,000 kgm. horizontal pendulum, with two components E. W., N. S., one a 1,000 kgm. vertical pendulum, and a 17,000 kgm. (nearly 19 tons) horizontal one. It may be mentioned that the great weight (1,000 kgm.) of these pendulums is necessitated by the magnification (200 for the 1,000 kgm. and 2,000 for the 17,000 kgm.) desired and from the fact that the registration is mechanical where friction has to be overcome, which, of course, is absent in the photographic apparatus. The chamber is excessively moist, apparently saturated, and many vessels of chloride of calcium are in use for absorbing the moisture. The roof or rather the ceiling is of cement with I irons. On these latter, by chains, hangs the wooden floor, so that walking about does not affect the pendulums. Atmospheric electricity, together with the electric discharges by rain form a particular line of observation and study here. In the absence of the director, various seismic phenomena were discussed with Professor Zoeppritz and Dr. Linke, recently returned from the earthquake station at Apia, Samoa. The workshops and establishment of Spindler and Hoyer were visited with profit; their specialty is earthquake instruments.

At Strassburg, the central station for Germany, and the central bureau for the International Seismological Association, the various seismographs were examined. The Director is Professor G. Gerland, founder of the association; the active investigator is Professor Rudolph; Dr. Mainka has charge of the instruments; and several specialists are generally engaged here. The examinations of the various instruments and the discussion with the scientists there of the many questions involved in the reading and study of seismograms were of undoubted value to the writer. Amongst other things, the desirability and value of establishing a station at Dawson was pointed out to me. It must be admitted that the reasons that were advanced were valid, and it is to be hoped that at no distant day Canada may add such an important station as one on the Yukon would be, to the series encircling the world.

During my stay in London a visit was paid to the earthquake station at Shide, Isle of Wight, where I met the veteran and eminent seismologist Professor John Milne. There are here two 100-pound pendulums, with mechanical registration, supported by the same iron column, and three with photographic registration. The time-record is hourly, making it thereby rather difficult to obtain very precise readings as regards time on the seismograms. The detached building for the photographic seismographs

is heated in the winter by means of a gas stove or jets, so that the seasonal fluctuation of temperature is confined within about 10° F. By an electrical device on one of the 100-pound pendulums an alarm is sounded when the amplitude becomes large, so that the observer is immediately informed of the occurrence of a severe earthquake, a convenience which cannot be carried out with photographic registration. Milne says he notices more movement of the pendulum due to rain, loading of valleys by water, than to barometric pressure.

In London the establishment of Negretti and Zambra was visited and the various types of meteorological instruments examined in detail. So far no satisfactory device has yet been invented for recording snow-fall, and the apparatus having a float in water for registration is unsuited for our rigorous winter weather. The meteorological station at Camden Square was visited, also the central station and forecast office under Dr. W. N. Shaw, where I was particularly interested in the micro-barograph (20 magnification). It gives relative records of atmospheric pressure, not absolute ones. It is believed by the writer that by means of this instrument some of the pulsations, micro-seisms, that we find recorded on seismograms may be explained and their cause determined. The introduction of this instrument for the study of meteorological phenomena is yet new, so that its service and value are yet unknown.

The large works of Troughton and Simms at Charlton were visited in connection with the large meridian-circle which they are building or have just built for our observatory, and I attended to its shipment.

I next proceeded to the Physical Laboratory and Meteorological Station near Richmond, and was most cordially received by the director, Dr. Chree. Regarding anemographs of the Robinson and Dines types, it was learned that the former gave a good average velocity but did not show gusts, and the larger the cups the more would gusts be smoothed out on the records, i.e., the cups would be made to spin rapidly and continue to do so after the gust had ceased. In the Dines, however, which depends upon pressure, this would not be the case; on the other hand, as the Dines depends upon pressure and this varies as the square of the velocity, it is not well adapted for small velocities. Examining a Dines anemogram it showed the wind (pressure) to be very variable, changes of from 12 to 2 miles an hour occurring continually within say fifteen minutes. If one drew a smooth curve through these oscillations a fair counterpart of the record of the Robinson would be obtained. For temperature record an electrical thermograph, Callendar method, was considered the best. The writer drew attention to the unsatisfactory results obtained for relative humidity due to the non-accordance of the tables for reduction. It was admitted that the problem was a difficult one, and particularly for low temperatures not much reliance can be placed on the deduced humidity. The hair-hygrometer was considered to do fairly good relative work, but its zero is not reliable. The three hours spent at this institution were most fruitful.

On the following day a brief visit was paid to the Solar Physics Observatory, South Kensington, and the larger problem of 'World Weather' discussed with Dr. W. J. S. Lockyer. It is a subject to which he has paid special attention.

TERRESTRIAL MAGNETISM.

During the past season the observatory began systematic observations for terrestrial magnetism. Mr. Geo. White-Fraser, D.T.S., was the observer, assisted by Mr. J. W. Menzies. Observations before and after the season's work were made at the Magnetic Observatory at Agincourt, near Toronto. For comparison several stations were occupied where officers of the Carnegie Institution, Washington, had observed the preceding year. Besides Agincourt, 32 stations were occupied, their names and position being shown on the accompanying map as well as in the tabular statement of results.

All the magnetic observations were made with a 'Tesdorpf' No. 1977, to be described more fully hereafter. Observations for time and latitude were made with an 8-inch alt-azimuth.

The following instructions were issued to the observer: Until the arrival of the sidereal chronometer, the pendulum apparatus will not be used, and the observations will be confined to those of terrestrial magnetism. As a general guide, as far as applicable to the particular form of instrument (Tesdorpf), the 'Directions for Measurement of Terrestrial Magnetism' given in Appendix 8, Report 1881, United States Coast and Geodetic Survey, will be followed. The records will be kept in their chronological order in a blank book, and in a manner similar to those in the above 'Directions.'

It may be noted that for declinations it is desirable to obtain the diurnal variation, for which purpose the observations should be begun before 7 a.m. and continued until the maximum reading has been reached and passed; and observations again begun shortly after noon, and continued till the minimum has been reached and passed. The mean between the east and west elongations will then be taken. Care must be exercised to remove the torsion of the fibre. Another observation will be taken at about 6 p.m., magnet erect and inverted for the declination.

The magnetic station is to be tied in distance and azimuth to the astronomic station (pier) of the place, and the pier to the nearest established corner, preferably the intersection of the sides of two streets. In case observations are taken where there is no astronomic pier, then connection will be made with some established corner as indicated above. Azimuth of the reference object will generally be taken by the sun. However, if the sun is obscured and Polaris available at night, the latter may be used for azimuth. Latitude may be obtained with sufficient accuracy by meridian altitudes of the sun. In the description for each station it is desirable to note in a general way (in the blank book) the topographical features, the geological formation, nature of any rock exposures and such other information that may assist in interpreting both magnetic and pendulum observations. The height of the top of the astronomic pier above the nearest point of the railway will be determined, and the position of the point with reference to the railway station given. Care should be taken that there is no magnetic substance (knife, keys, buttons, watch, suspenders, steel wire in hat rim) about the person observing.

Description of the Tesdorpf No. 1977.

This type of magnetic instrument was constructed by Tesdorpf of Stuttgart, according to the designs of Eschenhagen. The instrument has been extensively used in Germany, and was used on the German South Polar Expedition in various capacities: during the sea-voyage for the determination of the constants of the ship's magnetic instruments; at the winter stations for absolute measurements; and on the sled excursions in the south polar region; in every case did it serve its purpose well. One of the particular merits which the Tesdorpf has attained is the care which is bestowed upon the selection of thoroughly non-magnetic material in the construction of the instrument.

The Tesdorpf of the Dominion Astronomical Observatory consists of:—

1. Theodolite and Tripod—for the measurement of horizontal angles.
2. Declinatorium for pivot and fibre suspension.
3. Dip circle.
4. Magnetometer—for measuring horizontal intensity by means of deflections and oscillations—together with the intensity magnet. The parts 2, 3, 4 all fit snugly on the central part of the theodolite.

In the following description of the various parts the designations by letter refer to plates 3 and 4. On the two plates the same part has the same letter assigned to it.

On Plate 3 we have a view of the whole apparatus, exclusive of tripod, and on Plate 4 a view of the magnetometer on a larger scale.

The Theodolite.—It is mounted on a plate *U*, Plate 3, which in turn is secured to the tripod by means of a large milled-head screw, the latter serving also to hold the instrument firmly to a board in the packing box. The instrument is made of brass, bronze and magnalium. The limb is movable, is graduated to 20′ spaces, the graduation marks terminating in points, and is numbered to individual degrees. The diameter of the limb is 12 cm., and the reading is effected by two microscopes carrying each a ruling of 10 divisions covering two consecutive graduations on the limb, i.e., 20′, so that the divisions of the microscope represent 2′ and may be read readily by estimation to tenths, i.e., to fifths of a minute. As the theodolite must be used as a stand for the declinatorium, dip circle and magnetometer, the centre of it is free therefor. As the telescope *O* is mounted at the edge of the limb, a counterweight (not shown in plate) is attached at the opposite side. A circular level is mounted on one of the arms of the theodolite, and a striding level *L* is provided for the horizontal axis of the telescope. The telescope has a glass diaphragm attached to the tube of the ocular, having four ruled vertical lines, two very close in the centre and the other two symmetrically situate thereto. For illumination of the diaphragm there is a small opening in the tube of the eye-piece over which is an adjustable mirror *k* by means of which and a glass prism below the opening, light can be thrown on the lines of the diaphragm. The telescope, when observing for declination, is adjusted for focus by means of the reflected image of the lines by the mirror within the declination magnet. The adjusting for focus of object is done by moving the tube carrying both ocular and diaphragm in or out. The telescope being fixed in its Y's, it cannot be inverted.

The Declinatorium.—For the determination of magnetic declination two distinct methods are available; one is by supporting the magnet on a pivot, a fine point; and the other by suspending the (another) magnet by a fibre. Lamont, 1841, who was one of the early observers and investigators after the theory of terrestrial magnetism was placed on a scientific basis by Gauss, showed the preference of small suspended magnets to large ones, and furthermore believed in the greater accuracy attainable by suspension than by support on the pivot, on account of the friction which is always associated with the latter method. Eschenhagen, on the other hand, believed that for field observation where the instrument is subject to the effect of wind, that the pivot is preferable to suspension, especially if the pivot is made very fine—a needle point. It is with a view of meeting both cases that provision is made.

Taking first the pivot declinometer, a, a_1, Plate 3. On account of the difficulty of tempering steel to any great depth from the surface and for specific magnetic reasons, more effective permanent magnets can be produced by building them up of thin laminæ of steel, each of which is separately magnetized, than by magnetizing a solid bar. The magnet a_1, is composed of four magnetized lamellæ placed parallel to each other and separated by 2·5mm. The outer ones are 60mm. long and the inner ones 58mm. Their width is 10mm., and the whole magnet weighs 10 gr. As it is desirable to have the magnet invertible, it is provided with a double agate cap firmly secured in a hollow cylinder having a milled-head screw at each end. The construction of this double agate cap required infinite pains and labour, and great care must be exercised to preserve its virtue. At each end of the magnet there is a plane mirror for reflecting the lines of the diaphragm. Each mirror is adjustable with reference to the horizontal axis of the magnet.* As a rule the observations are made with the telescope pointing north, i.e., with reflections from the south mirror. The inversion of the magnet is effected by a skeleton carrier terminating in the milled-head seen at the

* See Terrestrial Magnetism, Vol. VII., 1902, p. 59, 'Ueber den Einfluss der Spiegel-Collimation bei Spitzen-Aufhaengung auf Declinations-Messungen.'

right-hand end of the chamber. Not only can this carrier be revolved, but within it are two forks or clamps which can be closed or opened for grasping and releasing the magnet. It will be observed that the inversion of the magnet is made without handling it or opening the chamber. As the position of the pivot when the magnet is swinging freely is in the centre of the chamber, it is necessary for the inversion of the magnet that the pivot be removed. This is done by means of the projecting screw on top of the chamber, which lowers and raises the pivot. The pivot itself is a very fine needle, the point of which would readily be broken off, were one to attempt to invert the magnet before first lowering the pivot. In the older form of instruments where heavier magnets were used, it was customary when the pivot was abraded through friction to regrind the point. This was always done at the sacrifice of the tempering. In the present case, a damaged pivot is replaced by a new one which can readily be inserted in its place and its proper height given by a special measuring contrivance supplied with the instrument. The left-hand end of the chamber is covered with a removable plane-glass front towards which the telescope is pointed when observing.

The fibre declinometer V_2 D_2 is seen on Plate 3. It consists essentially of a suspension tube, and a chamber with copper damping in which the magnet m is suspended. The chamber consists of two parts, D_2 and a similar one for the other side, both of which can be removed by unscrewing. In each is a heavy hollow cylinder of copper, within which the magnet moves. The ends of the chamber are covered by two glass fronts, both of which have ground parallel-plane surfaces. Beneath the covering cap V_2 is the screw for adjusting the length of the fibre. This screw passes through the 'torsion' head, moving over a graduation of 12 divisions for the circle, i.e., the intervals are 30°. The small screw b_3, and a similar one on the opposite side, when removed permits lifting off the upper part, when necessary for renewing the fibre. The movable plate y_1, serves for clamping the stirrup from which the magnet is suspended. It is necessary to clamp the stirrup when inverting the magnet, as well as when inserting the magnet, otherwise there would be danger, if not certainty, of breaking the fibre of brass, which when once done by an observer will ensure in the future due caution, as it is a rather trying process to replace it. For security against the dropping of the magnet in case the fibre should break, a pin, hidden in the photograph, passes through the large opening in the stirrup. Before renewing the fibre the pin must be removed by unscrewing, so that the stirrup may be taken out. The pin is also left out when putting in a new fibre until the torsion of the fibre has been removed by means of the small spherical weight T_1, whose mass is the same as that of the magnet m. Similarly the cylindrical weight T is used for removing the torsion from the fibre from which the intensity magnet M is suspended, to be referred to later. The declination magnet m is a hollow cylinder 35 mm. long, and its external and internal diameters 12 mm. and 8 mm., respectively. Within it at the centre and facing its south pole is a mirror for reflecting the lines of the diaphragm of the telescope. For inversion it is provided with two diametrically opposite small suspension bars. For inserting the magnet as well as for inverting it, the part D_2 or the opposite one must be first removed.

The Dip-Circle, J. Plate 3.

The dip-circle is composed of magnalium. The glass front is hinged at the bottom. The circle, 11·4 cm. in diameter, is graduated into 20′ spaces, and the reading is estimated with a magnifier to tenths thereof. Two dip-needles are provided. Instead of terminating in points, as is usual, the needles have rounded ends, and for reading on the graduated circle two short diametrically opposite lines have been cut with a diamond at the ends of each needle. The needles swing just in front of the graduated circle. The pivots of the needles, with which they rest on the horizontal agate supports, have a diameter between ·3 and ·4 mm. The small diameter reduces the error of eccentricity. The needles are placed by means of specially provided pincers

P upon the two forks beside the agate supports, then by moving the lever at the back of the dip-circle the forks are lowered and the needle swings on its support. It is found that it will swing a long time, showing thereby the trueness of the agate supports as well as of the pivots; even within the space of a 20′ division on the circle these oscillations are noticeable. For reversing the polarity of the needles, it is placed on the wooden block *F* in which there is a recess for the needle, and then by means of the two bar magnets *R* the reversal is effected. For cleaning and keeping the pivots clean and free from dust, elder-pith is provided. In the photograph the needle is in position in the dip-circle.

The Magnetometer V_1M. Plates 3, 4.

The essential parts are the magnet *M*, the suspension tube *V*, the closed box with glass front and back, the telescope *h*, and the thermometer *Te*. The suspension tube is similar to the one already described. The box is made of wood in preference to aluminum, which had been tried. The carrier M_1 has its end covered with rabbit fur, and is raised and lowered by means of the button M_3. The magnet *M* is laid on the carrier which is then raised to the highest point, when with proper adjustment of the length of the fibre the stirrup will just reach the cross bars of the magnet, and the latter may now be pushed over so as to catch when the support is lowered. During this operation the upper part of the stirrup frame M_7 is clamped by means of the clamp moved by the plate *y*, as is done with the fibre declinometer. The pin referred to before, which prevents the magnet from dropping in case the brass fibre breaks is also applied here and is as shown in *M*. In Plate 4 the suspension fibre and attachment are hung outside of the tube in order to show the different parts. Immediately above the stirrup is the plane mirror M_8, which reflects the scale division ruled on a thin glass disk and mounted in the side of the box, immediately in front of the object glass of the small telescope *h*. *T* is the torsion weight, of mass equal to that of the magnet *M*, and *i* is a protecting cap screwed over the stirrup when not in use, and when the suspension tube is removed from the box. Near the end of the telescope is seen a hole over which there is a circular adjustable mirror for throwing light on the scale and mirror. For the determination of the horizontal intensity two distinct operations are necessary; one is, by observing oscillations to be more fully described later, for which the immediately preceding described form of magnetometer is adapted; and the other is by observing deflections by a magnet whose magnetic moment is known. In Plate 3 will be seen the two arms, *A* and a similar one on the other side, into which the intensity or deflecting magnet *M* is placed. These arms are firmly secured to the theodolite frame by means of the binding screws *X*, and always fixed in exactly the same position. The arms are hollow cylinders and have the greater part of the upper half cut away for insertion of magnet. One edge of the remaining part of each has a millimeter scale on silver for giving the distance of the deflecting magnet from the centre of the instrument, and the brass millimeter scale bar, *Q*, which can be inserted through the arms, serves as a check for measuring the distances between various positions of the intensity magnet, when used as a deflecting magnet. The lower side of the arms is slotted for the adjustable blocks $g_1 \ldots\ldots g_8$, which can be clamped at fixed distances, and against one or other of which the magnet rests when observing. As it is important to know the temperature of the magnet, the thermometer *Té* is inserted into the arm, and to protect against the effect of change of temperature as much as possible the aluminum cylinders *H* (the second one is not shown) are slipped over the arms, being held by clamps over the binding screws *X*. The diameter of the cylindrical thermometer bulb is such that it readily enters the magnet when both are in position in one of the arms.

The remaining illustration on Plate 3 is *B*, which is the ordinary form of compass, and can also be mounted on the central part of the theodolite. The graduation on it

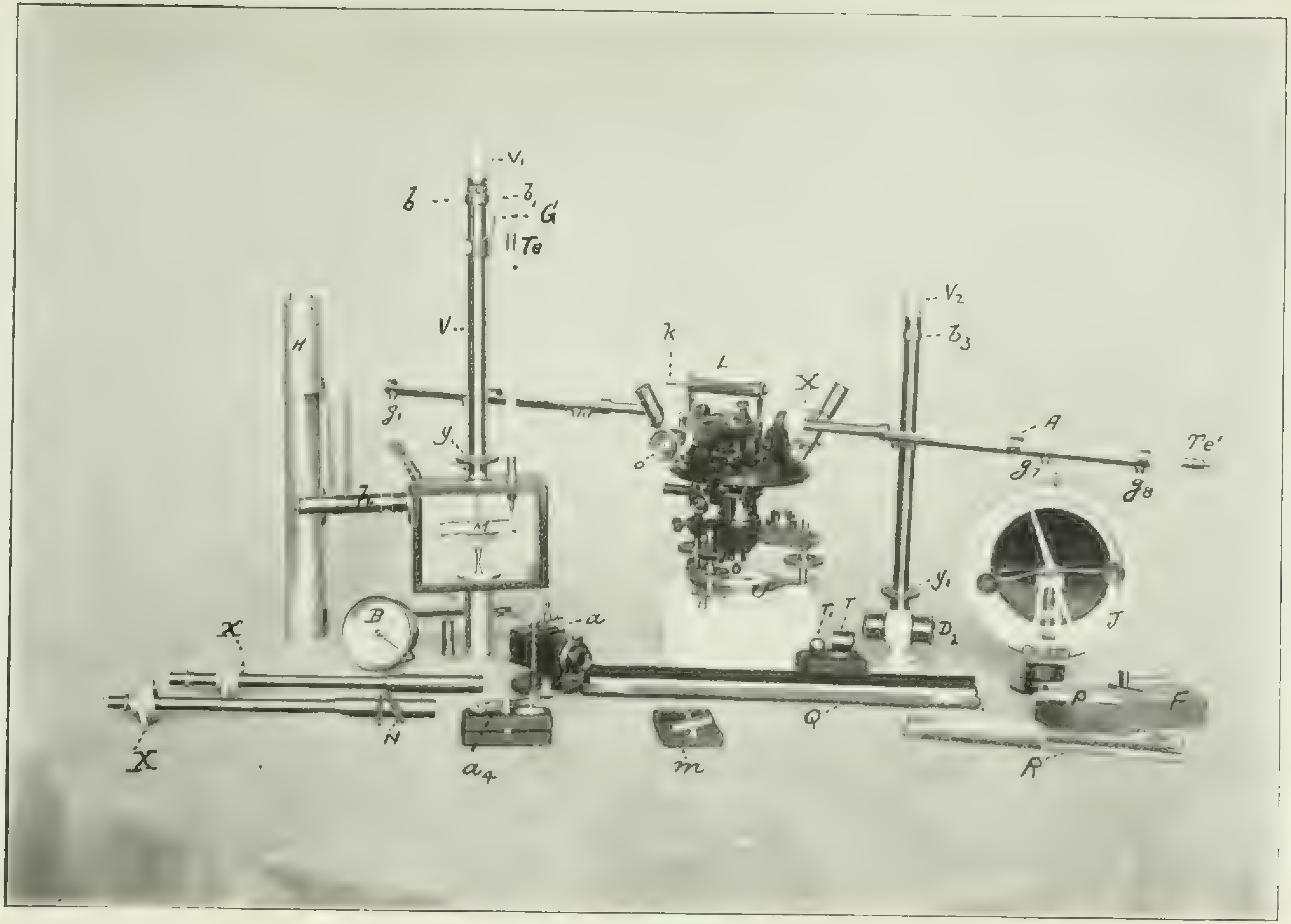


Fig. 3. Tesdorpf Theodolite Magnetometer.

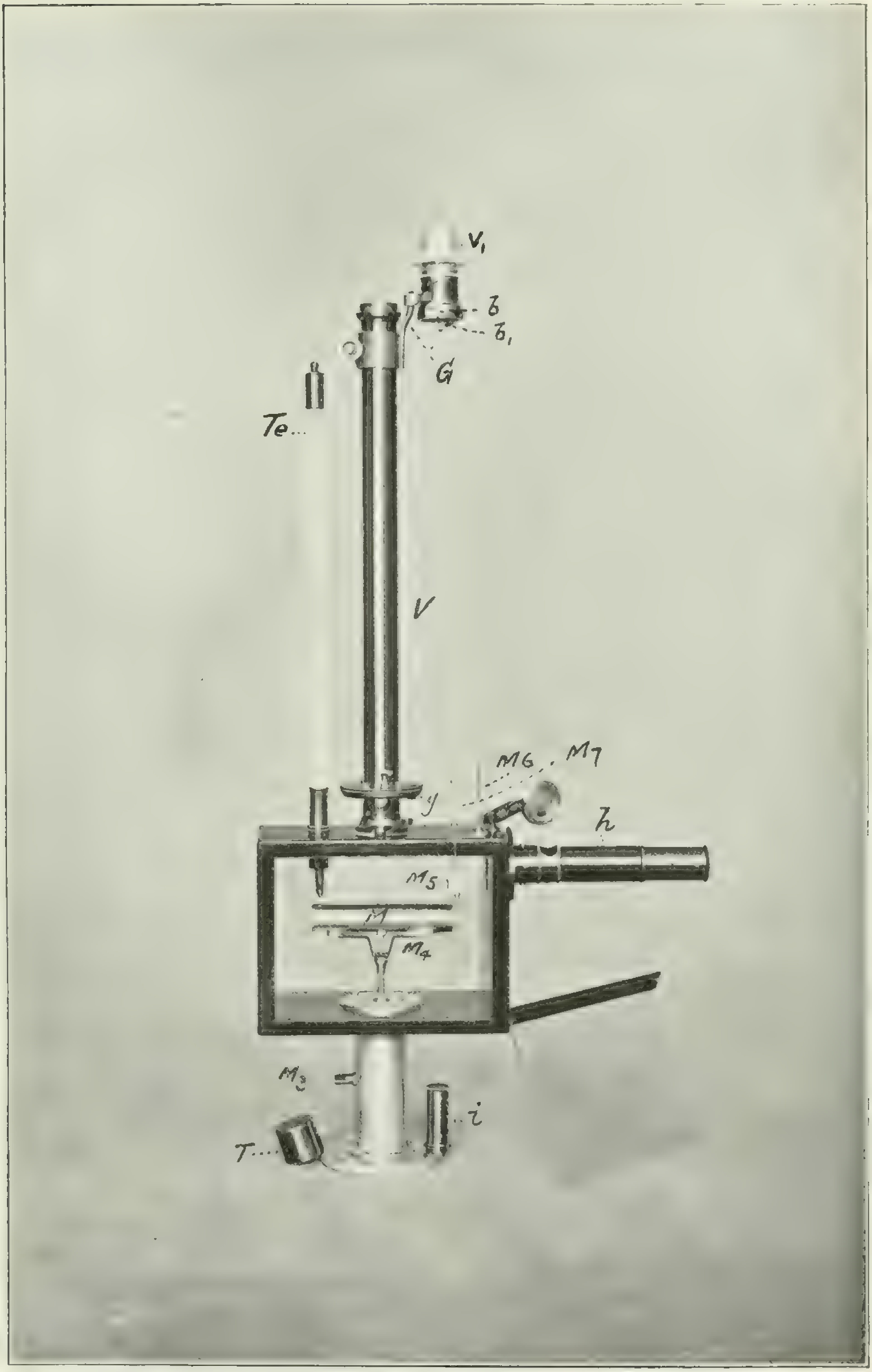


FIG. 4.—Magnetometer.

is to individual degrees and by estimation can be read to fifths or 12′. The compass serves as a rough check on the magnetic declinations.

The Observations.

After selecting a suitable station, and if possible one that may again be occupied at a future date, the first observation is generally for the determination of the astronomical meridian and obtaining the azimuth or true bearing of some prominent objects. The azimuth of a reference object is most readily obtained and with sufficient accuracy from the observed altitude of the sun, circle left and circle right. As 1′ is about the limit of accuracy of reading the direction of the magnet, on account of the continuous fluctuations, it is useless to attempt greater precision for the astronomic meridian. For the purposes of computing the spherical triangle for azimuth the latitude can generally be taken with sufficient accuracy from a map, otherwise a few meridian altitudes of the sun, circle left and circle right, at noon will supply the data. The difference between the astronomic bearing of the reference object and its magnetic bearing gives the magnetic declination. It is west or + declination when the magnetic north lies to the west of the astronomic north; and east or − declination when it lies to the east. As the Tesdorpf 1977 is not supplied with a mounting having a vertical circle, it is necessary to carry along another instrument wherewith the astronomic observations can be made, as well as any survey to connect the magnetic station with some permanent reference point.

All the magnetic observations were made in a specially made tent, ventilated, and all parts, of whatsoever nature, were non-magnetic.

The observations with the pivot-declinometer are simple, but great caution must be exercised not to damage either the fine needle pivot or the finely ground agate cup or support.

The magnetic theodolite is first accurately leveled. Before mounting the magnet chamber on the alidade, the skeleton carrier is withdrawn, first removing, however, the glass front which locks into the carrier frame, and making sure that the pivot is lowered. The magnet is then placed with the south end towards that end of the chamber having the plane-parallel glass front within the open jaws of the clamp, the movable milled-head is turned from A to Z with reference to the index mark; the A on the head signifying 'open' (auf), and Z 'closed' (zu). The carrier is then carefully put into the chamber with an upward tilt, to avoid any possibility of touching the lowered pivot, snapped into place by the small spring at the carrier-head end of the chamber. The glass front is replaced, and the chamber is now placed on the instrument and clamped in position. The telescope is turned so as to point approximately north. The magnet is released by moving A into co-incidence with the index mark when it will rest at each end within the copper blocks. The pivot is then raised to its full height, and the magnet will now swing freely. Looking into the telescope, we see directly in the lower half of the field the lines of the diaphragm, while the reflected image by the mirror of the magnet will move to and fro across the field, providing the setting is fairly near the meridian, which if not is readily made so by turning the upper plate of the theodolite on which the telescope is mounted in the proper direction. There may be a little difficulty at first in seeing the image at all; however, by tilting the telescope slightly, when its pointing is near the magnetic meridian, a moving 'half moon' will be seen, whereupon accurate adjustment can be made, so that the direct and reflected images cover each other. For seeing the lines well, the small mirror on the telescope requires careful setting. Dependent upon the setting of the mirror, a small change may cause the lines to appear dark on a light background, or light on a dark background. The pointing for the magnetic meridian is made by observing small symmetrical oscillations of the reflected image of the middle lines about the direct image, instead of co-incidence, as the magnet is never at rest, using the tangent screw of the upper plate of the transit for fine adjustment.

The two microscopes are then read, which gives a reading for the magnetic meridian. The operation is repeated after first lowering and then raising again the pivot. The magnet is then inverted, lowering the pivot, however, first, and after inversion raising it again. Another duplicate set of readings is taken as before. The mean local or standard time should always be noted for the observations.

It is desirable when observing for declination that the daily or solar-diurnal variation be determined. The north end of the magnet reaches its most easterly deflection or elongation shortly after sunrise and its most westerly deflection or elongation about an hour after noon. The average time for the year for eastern elongation is about 7h 30m a.m.; for western elongation about 1h 30m p.m. In its daily movement the direction of the magnet crosses the magnetic meridian twice, once at about 10.30 a.m., and again at about 7.30 p.m. In summer, the times are a little earlier and in winter a little later than those above given. The observations for eastern elongation are commenced a little before 7 a.m., and readings are noted every 15 minutes until the maximum deviation is reached and passed. Similarly for western elongation, readings are begun about 12h 30m p.m. and continued until the western maximum has been reached and passed. The difference between the east and west maxima gives the daily range, or more precisely the range for the day of observation, for the daily range is subject to an annual inequality, which is greater in summer than in winter, the difference being between 3′ and 4′. The observations for elongation are taken in the same position of the magnet, so that the mean of the east and west readings for the magnetic meridian must be corrected for the position of the magnetic axis, obtained from the readings of the magnet direct and inverted, or N up and N down. Beside the observation for elongations, another and direct observation for the magnetic declination is made, generally about 6 p.m., when the direction of the magnet is approaching the magnetic meridian, and with the magnet direct for the one set of readings, and inverted for the other set. From this latter observation the position of the magnetic axis of the magnet is obtained, necessary for the reduction of the observations at elongation.

The observations with the fibre declinometer are similar to those of the pivot declinometer, with the addition, however, of elimination of the torsion of the fibre. The torsion is removed by suspending from the fibre a small brass weight already referred to, of the same mass as the declination magnet. When it comes to rest the torsion is removed; by means of the torsion head the line of detorsion is placed in the magnetic meridian, in which position it is parallel to the sides of the chamber or in line with the telescope. Several trials may be necessary to effect this. It is desirable at every station to suspend the weight to test the accuracy of the position of the line of detorsion. In case the fibre should break, it is necessary after inserting a new fibre to remove the pin passing through the stirrup to allow the fibre to untwist, when the pin is again put in place. For the determination of the magnet inclination by means of the dip-circle, the following observations are necessary: The inclination is measured in the plane of the magnetic meridian. When the north end of the needle dips below the horizon the inclination is considered +, when above the horizon —. The needle may be placed in the magnetic meridian, i.e., the direction of the axis of needle east and west, either from the known direction of the magnetic meridian, or by means of the needle itself. Observations for the determination of magnetic declination generally precede those for inclination, when the direction of the magnetic meridian has been obtained, and the dip-circle can then be readily placed in the proper position. If the direction of the magnetic meridian is not thus known, we obtain it from four readings of the inclination needle when pointing vertically, which it does when in the magnetic prime vertical. The four readings on the azimuth circle are taken in the positions: Face of circle south with face of needle successively south and north; and next face of circle north with face of needle successively north and south. The mean of the four readings on the

azimuth circle $\pm$ 90° will then define the direction of the magnetic meridian in which the observations for dip are made. These latter are similarly made in four positions as above, only that the face of the circle and the face of the needle are alternately east and west. Another set is taken with the polarity of the needle reversed, so that for a complete determination of the magnetic inclination we have eight individual observations. The object of the reversals is for the elimination of errors. By reversing the dip-circle its index error is eliminated as well as any small error in the level or the verticality of axis; by reversal of the face of the needle on the agates the error arising from imperfection in its transverse balance and from non-coincidence of its geometrical and magnetic axes is eliminated; and by reversal of polarity the effect of the unsymmetrical distribution of the mass with reference to the axis of rotation of the needle is eliminated.

For reversing the polarity of the needle it is placed in the block, *F*, provided therefor and secured in position by a spring clamp through which the one end of the axis passes. The two bar magnets, one in each hand, are then brought with opposite poles against the clamp, and held at an angle of about 30° to the horizon. They are then drawn slowly and simultaneously over the needle and along the ledge of the block to maintain uniformity of direction. The end of the needle having north polarity has the north end of the bar magnet passed over it to change it to south polarity, and similarly the end of the needle having south polarity has the south end of the other bar magnet passed over it to change it to north polarity. These strokes are repeated four times, each one passing completely over the needle and returning a few inches above the needle by a uniform motion of both hands to the clamp for repetition. The needle is then turned over and the operation is repeated. To correct for any inequality in the intensity of the two bar magnets, one-half of the operation of reversal of polarity of the needle may be made with the north and south poles of the bar magnets held in one position, then exchanging the magnets in the hands inverting them and applying the other two poles to the other side of the needle.

The Determination of Horizontal Intensity.

The principle involved in the determination of the horizontal intensity is very simple. We observe in the one case the time of oscillation of the horizontally suspended intensity magnet. Here we have the combined effect, usually designated by $m\ H$, of the magnetic moment of the oscillating magnet and of the earth's magnetic energy, acting as a couple upon the magnet. In the other case, that of deflection, we observe the differential effect, usually designated by m/H, of the same two forces. The value of the quantities entering into the two equations for $m\ H$ and m/H respectively being known, either from direct observation or as constants, m and H can be eliminated. The total intensity F follows then directly from the relationship $F = H \operatorname{Sec} I$, where I is the inclination or dip. For observing oscillations the intensity magnet is suspended from the fibre in the magnetometer. When the magnet is at rest the reflected image of the centre of the scale, by the small mirror above the stirrup, should be coincident or nearly so with the vertical thread. The oscillations should be in a horizontal plane and up and down motion avoided. It is customary to observe every fifth transit of the image, counting transits both to the right and the left. Before beginning recording, however, we observe a number of transits, noting the time of the first and last transit by a mean time chronometer, for getting the approximate interval for five transits, so that one need not keep the eye constantly at the telescope, nor keep up the consecutive counting of transits one, two, three and so on, but instead, knows in advance within a second or so when the respective, fifth tenth, fifteenth,......transit will take place, and be ready to note by 'eye and ear,' the time being given by the half-seconds beat of either a pocket or box mean time chronometer, and estimated to a tenth of a second. If the first transit, say to

the right, be denoted by 0, the following transits to be noted to the right will be 10, 20, 30 and so on, while those noted to the left will be 15, 25, 35 and so on. By noting the transits to the right and to the left, the effect of any change in declination during the observation is eliminated. In order to obtain an accurate value of the time of one oscillation, we compare the times between two transits in the same direction separated by an interval of many oscillations, generally a hundred; and from the mean of a group of about 10 such intervals, an equal number of which are to the right and to the left, we get the time of one oscillation. In connection with the observations for oscillation the temperature of the magnet is noted by the thermometer, the bulb of which projects within the oscillation box; and the value of the torsion co-efficient is obtained from the change of horizontal circle reading by turning the torsion head three divisions (90°) to the right and then to the left from its position during the oscillations.

In observing for deflections, we obtain the ratio of the magnetic force of the deflecting magnet, being the one used for oscillations, and the horizontal force of the earth's magnetism. The declination magnet is suspended in its chamber as when observing for declinations, the line of detorsion being in the plane of the magnetic meridian. Before placing the deflecting magnet in position, pairs of blocks in the deflecting arms are fixed at equal distances from the centre of the instrument by means of the graduations on the arms, as well as the distance between them by the millimetre-scale brass rod. The deflecting magnet is then placed in position against the block and the declination magnet is suspended at the same height as the deflecting magnet. The horizontal plate of the theodolite with telescope is then turned until the reflected image of the diaphragm by the mirror in the declination magnet coincides with the direct image. Then the deflecting magnet is at right angles to the deflected or declination magnet and the horizontal circle reading is noted. The deflection angle is the difference between this latter reading and the reading of the horizontal circle for the magnetic meridian. Another reading is now taken at the same distance, but with the position of the poles reversed, *i.e.*, if the first position was with north end of magnet east, the next will be with north end west. Then the magnet is placed into the other arm and at the same distance as with the former, and readings similarly obtained for north end east and north end west. The whole of these four readings are now repeated, but at another distance equally set off by the movable blocks in the arms; the shorter distance should be about or a little less than four times the length of the deflecting magnet. In each of these two sets, theoretically the mean of two readings for two symmetrical positions of the deflecting magnet with reference to the declination magnet should give the horizontal circle reading for the magnetic meridian, and the difference between the two readings twice the angle of deflection of the deflecting magnet against the directive force of the earth. So, too, should the mean and difference of the two readings for one distance on one arm, but with magnet north end east and north end west, give respectively the magnetic meridian and double the angle of deflection. The time of beginning and ending of the observations is noted and also the temperature of the deflecting magnet by inserting the thermometer into the arm and magnet.

The following quantities enter into the computation for the reduction of the observations of oscillations and deflection for obtaining the value of the horizontal component of the earth's magnetic force:—

T_0 = Observed time of one oscillation.

T_1 = Observed time of one oscillation corrected for rate of chronometer, and arc of vibration. For small arcs the latter correction is very small and may be neglected.

T = Time of time of oscillation, corrected for rate.

$\frac{h}{f}$ = Ratio of the force of torsion of the suspending fibre to the magnetic directive force.

q = Correction for the decrease of the magnetic moment of the magnet produced by an increase of temperature of 1°.

K = Moment of inertia of the magnet, inclusive of stirrup and other appendages. (This is constant for the same magnet and suspension, but varies slightly with temperature, owing to the expansion of the materials.)

μ = Increase in the magnetic moment, m, of the magnet produced by the inducing action of a magnetic force equal to unity of the system of absolute measurement.

m = Magnetic moment of the oscillating or deflecting magnet.

H = Horizontal component of the earth's magnetic force.

u = Observed angle of deflections.

$a\, a_1$ = Semi-arcs of oscillation at the beginning and end of observation. The correction to T_0 for arc is $\left(1-\frac{a\,a_1}{16}\right)$ where $a\, a_1$ are expressed in radians.

r = Distance, corrected for error of graduation and temperature, between the centres of the deflecting and deflected magnets.

P = Co-efficient depending upon the distribution of magnetism within the deflecting magnet, and is determined experimentally from a series of observations by means of deflections at two or three distances. To find P let A = value of $\frac{m}{H}$ for the shorter distance r, and A' = value of $\frac{m}{H}$ for the longer distance r_1, then $P = \dfrac{A - A'}{\frac{A}{r^2} - \frac{A'}{r_1^2}}$

We have then

$$T_1 = T_0\left(1+\frac{s}{86400}-\frac{a\,a_1}{16}\right)$$

where s is the rate per day, + for losing and − for gaining rate.

$$T^2 = T_1^2\left(1+\frac{h}{f}\right)\left(1-(t'-t)\,q\right)\left(1+\mu\frac{H}{m}\right);\quad m\,H = \frac{\pi^2 K}{T^2}$$

$$\frac{m}{H} = \tfrac{1}{2}\, r^3\left(1-\frac{P}{r^2}-\ldots\right)\left(1+\frac{2\mu}{r^3}\right)\operatorname{Sin} u$$

or

$$\frac{H}{m} = \left[\frac{2\left(1+\frac{P}{r^2}+\ldots\right)}{r^3\left(1+\frac{2\mu}{r^3}\right)}\right]\frac{1}{\operatorname{Sin} u} = \frac{C}{\operatorname{Sin} u}$$

hence

$$\log H = \tfrac{1}{2}\left(\log\frac{H}{m}+\log m\,H\right)$$

The value of q for 1° centigrade for deflecting magnet 46 Tesdorpf as determined by Mr. R. F. Stupart, director of the magnetic observatory at Agincourt is ·00045; of the induction co-efficient μ = ·0000072, and $\log \pi^2 K$ at 0°C = 9·465511. The dimensions of the inertia cylinder used for the determination of K were:—

Length at 0°C = 94·49mm
Diameter 0°C = 10·11mm
Weight = 63·169 grammes

"The inertia cylinder used was that supplied with Kew magnetometer 48. In experiments it was suspended with silk thread below magnet and also for sake of comparison was placed inside No. 46 (Tesdorpf), the results being almost identical. $\frac{\Delta m}{m} = \mu \frac{H}{m}$ was determined by deflecting bifilar magnet, and from result the value of induction co-efficient = ·00000702 was obtained.'—(Stupart.)

In the accompanying table for Magnetic Results the following explanatory notes are added.—The stations are arranged in order of longitude. All the declination observations were made with the fibre declinometer. For eastern elongation of the magnet, observations were begun before 7 a.m. and readings taken every ten or fifteen minutes until the magnet had attained its most easterly position and begun its westerly movement. The maximum reading and its corresponding time were then taken for the easterly elongation; similarly it was done for the observations begun shortly after noon for westerly elongation, where the minimum reading and its corresponding time were taken. The position of the magnet was the same for both elongations. The mean of these two readings, corrected for axis of magnet, gives the horizontal circle reading for the magnetic meridian, and this reading, compared with the reading on the reference object, whose azimuth has been determined by observations, then gives the angle between the magnetic and astronomic meridians, *i.e.*, the declination, which is entered in the column 'Declination – Mean of Elongations.'

At nearly all the stations observations for declination were taken on two days.

The times recorded for the various observations were standard time for the respective place, and subsequently reduced to L. M. T., the local mean time for each place or station.

The accompanying map shows the position of the various stations given in the table, and the direction of the magnetic meridian at the respective stations or places.

Stations Occupied.

Following are the descriptions of the positions of the magnetic stations occupied during the past season. Besides these verbal descriptions there is on file a sketch for each station and photograph showing the position with reference to surrounding objects, lots, streets and natural features. The azimuth given is reckoned from the north through the east, from 0° to 360°.

Sydney, N.S.—Occupied October 29 to November 2, 1907. Latitude 46° 06′·6; longitude 60° 12′·0. This station is located in Victoria Park. Reference Object: Spire of Falmouth Street Presbyterian Church. Azimuth of Reference Object: 150° 02′·25. The surface is level and clear, with gradual slope to bay. Conditions apparently satisfactory.

Mulgrave, N.S.—Occupied November 4 to November 6, 1907. Latitude 60° 22′·5. Station located on clear spot east of I. C. R. station and one thousand feet distant therefrom. Reference Object: Spire of Methodist church. Azimuth of R. O. 71° 21′·55. The surface rises from water level at I. C. R. station to an elevation of about one hundred and ten feet at magnetic station. In the vicinity of the latter, it is much broken up, with many boulders and loose rock showing. The rock, however, did not, on trial, appear to affect the magnets in any way. The slope continued rising, being very uneven and covered with rough bush.

Antigonish, N.S.—Occupied November 7 to November 9, 1907. Latitude 45° 36′·6. Longitude 62° 43′·5. Station located in C. A. E. Tennis Court Grounds. Reference Object: Flag pole on post office. Azimuth of Reference Object: 123° 16′·3.

Pictou, N.S.—Occupied October 25 to October 28, 1907. Latitude 45° 37′·9. Longitude 62° 43′·5. Station located in C.A.E. Tennis Court Grounds. Reference Object: Spire of St. Andrew's church. There are two spires close together. The R. O.

is the lower one, and to the west of the higher. Azimuth of R. O., 180° 01′·65. Tennis Court is on level ground on the top of the somewhat rapid slope to the bay.

Truro, N.S.—Occupied October 21 to October 24, 1907. Latitude 45° 20′·2. Longitude 63° 15′·0. Station at entrance to Victoria Park. Reference Object: Spire of Presbyterian church. Azimuth of R. O. 139° 24′·4. Station on flat ground near river; the sides of the valley of which are distant two hundred feet to the west, about five hundred feet to the east, and rise to about two hundred and fifty feet. The valley narrows considerably in Victoria Park. The I. C. R. tracks are distant at least one thousand feet.

Pugwash, N.S.—Occupied October 18 to October 21, 1907. Latitude 45° 50′·2. Longitude 63° 40′·5. Station located in field belonging to Dr. Clay. Reference Object: The peak of the lighthouse roof. Azimuth of R. O. 334° 35′·0. Station at the mouth of the Pugwash river about fifteen feet above water level. Level and open ground.

Shediac, N.B.—Occupied November 16 to November 17, 1907. Latitude 46° 12′·1. Longitude 64° 31′·7. Station located in a field behind the Weldon House. Reference Object: Spire of Presbyterian church. Azimuth of R. O. 231° 33′·45. Ground level and clear, with gentle slope to bay.

Moncton, N.B.—Occupied October 14 to October 16, 1907. Latitude 46° 06′·8. Longitude 64° 42′·7. Station located in field below Minto Hotel. Reference Object: Spire of St. John's Presbyterian church. Azimuth of R. O. 34° 36′·6. Ground quite flat, no near buildings, river embankment one hundred and fifty feet distant.

Richibucto, N.B.—Occupied November 11 to November 13, 1907. Latitude 46° 40′·6. Longitude 64° 51′·7. Station located in post office grounds. R. O., flag pole of post office. Azimuth of R. O., 112° 56′·5. This station is favourably located, about ten feet above sea level. Surface level and clear.

Newcastle, N.B.—Occupied November 14 to November 16, 1907. Latitude 46° 58′·2. Longitude 65° 33′·0. Station located in field near I. C. R. station. R. O., spire of Presbyterian church. Azimuth of R. O., 21° 46′·0. All conditions apparently favourable. Surface level and clear. I. C. R. at least one thousand feet distant.

Bathurst, N.B.—Occupied November 18 to November 20, 1907. Latitude 47° 37′·5. Longitude 65° 39′·0. Station located in field belonging to Mr. S. Leger. R. O., spire of Roman Catholic church across channel. Azimuth of R. O. 91° 31′. All conditions favourable. Surface level and clear. Point about ten feet above sea level. I. C. R. tracks at least one thousand feet distant.

St. John, N.B.—Occupied October 1 to October 4, 1907. Latitude 45° 16′·7. Longitude 66° 00′·7. Station located on Gilbert property, facing Gilbert's lane to the north of the city. Reference Object, spire of Leinster Baptist church to left of hospital. Azimuth of Reference Object, 179° 16′·9. This station is situated in a field about 250 yards from the I. C. R. tracks and about one hundred and ten feet above them. To the north and west the surface rises abruptly in rocky hills, forming the right slope of the valley of Marshy creek, covered with rough brush. The station itself is on a knoll, with a rapid fall to the level of the tracks, which are about twenty-five feet above high tide level.

Mispec, N.B.—Occupied October 9 to October 11, 1907. Latitude 45° 13′·3. Longitude 66° 05′·7. Station located in neighbourhood of pulp mill. Reference Object, tower of pulp mill. Azimuth of Reference Object, 114° 12′·05. The surface is very broken and rough in this neighbourhood, with much rock and rough bush. To the northwest from magnetic station it rises rapidly to rocky elevation, probably

eight hundred feet above sea level. To the south and east it falls equally rapidly to a stream which falls into the bay about half a mile away. The station itself being probably three hundred and fifty feet above the sea level.

Matapedia, Que.—Occupied November 21 to November 24, 1907. Latitude 47° 56′·5. Longitude 66° 50′. Station located on the bank of the Restigouche river, on the field belonging to the Hunting Club, to the south of the I. C. R. Reference Object, cross on Roman Catholic church. Azimuth of R. O. 281° 21′·0. Conditions apparently favourable. Surface level and clear. Tracks six hundred and fifty feet distant. Certain amount of loose rock which, however, on trial did not affect the needle.

Megantic, Que.—Occupied September 20 to September 24, 1907. Latitude 45° 34′·4. Longitude 70° 53′·2. Station located in the southeast corner of field. Reference Object, flag staff of school house in Megantic. Azimuth of R. O., 329° 01·′95. The station is strictly not in Megantic, but in the village of Agnes across the Chaudière river. The surface is open, being cleared of bush, but large stumps left in situ, gently sloping towards the river and lake. No rock showing. At least one thousand feet from C. P. R. tracks.

Tring Junction, Que.—Occupied September 25 to September 27, 1907. Latitude 46° 15′·5. Longitude 71° 09′·7. Station located in field to west of Q. C. station. Reference Object, higher spire of Roman Catholic church at St. Frederick, two miles away. Azimuth of Reference Object, 29° 58′·33. The surface is level and open, no outcroppings, nor near bush. Station distant about two hundred and fifty yards from the Q. C. tracks and on a level with them.

Sherbrooke, Que.—Occupied September 13 to September 18, 1907. Latitude 45° 23′·9. Longitude 71° 56′·2. Station located on Pembroke avenue. Reference Object, spire of new Catholic church. Azimuth of Reference Object, 92° 56′·4. This station is on the public highway, at the intersection of Pembroke ave. and Victoria street. The former here terminates, and there is little prospect of the town extending in this direction. The ground is level and open and quite elevated above the valley of the Yamaska river. There were no outcroppings of rock in the vicinity.

Farnham, Que.—Occupied September 7 to September 11, 1907. Latitude 45° 16′·1. Longitude 73° 01′·5. Station located in field belonging to McCorguil Estate, south of C. P. R. tracks. Reference Object, spire of Methodist church. Azimuth of Reference Object, 36° 22′·46. This station is at least one thousand feet from C. P. Ry. tracks. The surface level, clear and open, no rock or bush.

Brockville, Ont.—Occupied August 31 to September 4, 1907. Latitude 44° 35′·9. Longitude 75° 33′·0. Station located in field belonging to Mr. C. S. Cossitt, near G. T. R. station and schoolhouse. Reference Object, spire of First Presbyterian church. Azimuth of Reference Object, 74° 13′·3. Surface level and open, no rock, no near buildings. Tracks three hundred yards distant.

Kingston, R.M.C., Ont.—Occupied August 19 to August 21, 1907. Latitude 44° 13′·8. Longitude 76° 28′·20. (R.M.C. observers.) Station located in playing field of R.M.C. Reference Object, spire of Brock St. Methodist church. Azimuth of Reference Object, 259° 18′·45. The surface conditions are apparently satisfactory. Ground level and open. The College is six hundred and twenty-five feet distant. The weather during the observations satisfactory. The declination, however, is so very much greater than might be predicted from the declination at Sharbot Lake to the northwest, and Brockville to the east, as to show some local influence, more or less constant. This deduction is strengthened by the fact that the east and west elongations observed independently on successive days corroborate each other very closely, with a range of about 15′, and the declinations taken at 5.30 p.m. on these successive days give an

average declination agreeing with the mean of the elongations within 1′. It is well known that some local influence renders the mariner's compass useless in that neighbourhood, and Capt. Russell-Brown, Instructor in Geodesy and Surveying at the R.M.C. stated that a compass survey there would not nearly close, and that he could get many varying declinations across the field.

Kingston, Old Artillery Barracks.—Occupied August 23 to August 25, 1907. Latitude 44° 15′·2. Longitude 76° 29′·2. Station a relocation of Capt. Lefroy's, in 1849. Reference Object, the north side of the western cross on 'House of Providence.' Azimuth of Reference Object, 155° 02′·26. The station is probably a correct relocation of Capt. Lefroy's within ten feet. The results obtained are probably not very reliable, as the Old Barracks (now used as a store) is within one hundred feet. The artillery stables (now in use) are within eighty feet. The armoury of the Kingston regiments within three hundred feet, and the Kingston Electric Railway runs to the southeast within two hundred feet and to the northwest within six hundred feet. All observations, however, were taken on Sunday, when the electric railway does not operate. The observations, however, for declination and dip (horizontal force was not observed) seem quite accordant. The range between elongations was 17′; the declination taken at 5.45 p.m. agrees within 1′ with the mean of the elongations and the dips agree with a range of 3′.

Kingston Junction, Ont.—Occupied August 27 to August 28, 1907. Latitude 44° 15′·2. Longitude 76° 28′·0. Station located in field belonging to Mr. Elliott. Reference Object, cross on St. Mary's cathedral in Kingston. Azimuth of Reference Object, 181° 37′·8. This station is proximate relocation of that occupied in 1906 by the Carnegie Institution, and which was described as being a given distance from two trees, and azimuth of the Reference Object 182° 26′·8. Where there are many trees it is a matter of uncertainty to select any particular two. The visible surface conditions appear favourable and although it appears likely that the same local disturbance that affects what might be calculated to be the three magnetic elements at Kingston city, would have some influence here, still the individual observations taken are closely accordant.

Sharbot Lake, Ont.—Occupied August 12 to August 16, 1907. Latitude 44° 46′·4. Longitude 76° 41′·2. Station selected in a field lying to the north of the railway station between the K. & P. track and an arm of the lake. Reference Object, pole of railway watering tank. Azimuth of Reference Object, 225° 56′·0. This station is situated on the top of the bank sloping rapidly to the lake, and about sixty feet above the water level. It is about eight hundred feet from the nearest point on the K. & P. tracks and about fifty feet above them. The surface surrounding the station is open and clear, with no apparent disturbing conditions.

Pembroke, Ont.—Occupied July 26 to July 28, 1907. Latitude 45° 49′·3; Longitude 77° 07′·5. Station selected in field belonging to Mr. Peter White, jr. Reference Object, spire of Presbyterian church. Azimuth of Reference Object 288° 56′·0. Surface clear and open, level. Apparently favourable conditions. Station about one hundred and ten feet above railway tracks and quite distant therefrom.

Barry Bay, Ont.—Occupied August 8 to August 9, 1907. Latitude 45° 28′·77. Longitude 77° 24′·6. Station selected in open ground near the school house. Reference Object, spire of Roman Catholic church. Azimuth of Reference Object 78° 10′·14. The surface is level and open, a low rocky knoll is situated about five hundred feet to the west, but in the near vicinity there is no outcropping. All conditions apparently favourable.

Mattawa, Ont.—Occupied July 23 to July 24, 1907. Latitude 46° 19′·7. Longitude 78° 41′·0. Station selected on Hudson's Bay Co.'s reserve. Reference Object, the flag-pole on the school house across the river. Azimuth of Reference Object, 138° 24′·9. Conditions apparently quite favourable, surface clear and sloping gradually to the water level at confluence of Mattawa and Ottawa rivers, on the point between which the Hudson's Bay Co.'s reserve is situated. From the water it slopes gradually up, culminating in the low rocky sides of the valley. No disturbing conditions apparent.

Joe Lake, Ont.—Occupied August 5 to August 7, 1907. Latitude 45° 35′·2. Longitude, 78° 46′·5. Station selected on 'Algonquin Hotel Reserve,' about three hundred and fifty feet south of the hotel. Reference Object, the peak of the south gable of the hotel. Azimuth of Reference Object, 310° 26′·0. It was difficult to find a convenient and favourable spot for a magnetic station. The surface is much broken up, covered with a dense bush, and much rock, which however, did not on trial appear to affect the needle. The station is distant about eight hundred and fifty feet from the Canada Atlantic Railway tracks and about forty-five feet above them.

North Bay, Ont.—Occupied July 18 to July 20, 1907. Latitude 46° 18′·3. Longitude 79° 24′·7. Station selected on waste ground at east extension of Sherbrooke street. Reference Object, spire of English church (on Sherbrooke street). Azimuth of Reference Object, 235° 50′·45. All this district is subject to the comment that rock is never very deep below the surface. On trial, however, bits of boulders did not apparently affect the needle. The surrounding surface is fairly level and clear and open.

Rose Point, Ont.—Occupied July 31 to August 4, 1907. Latitude 45° 19′·1. Longitude 80° 15′·0. Station selected on small island known as 'Sloop Island.' Reference Object, the pole surmounting the cupola on the northeast side of the Canada Atlantic Railway station. Azimuth of Reference Object 177° 38′·8. Sloop Island is not more than one-quarter acre in extent, and is on the west side of the narrow channel used by the boats plying between Rose Point and Parry Sound. It is a mere rock; the entire district is no better, being covered with only a few spruce and shrubs. The broken boulders scattered about affected the needle very greatly when brought to within five or six feet, and care was taken to remove all possible to a considerable distance. At the same time, the independent observations of the east and west elongations of declination, taken on three successive days, corroborate each other very closely, although the range is only 9′.

Sudbury, Ont.—Occupied July 15 to July 17, 1907. Latitude 46° 29′·0. Longitude 81° 00′·0. Station selected on waste ground on east extension of Minto street. Reference Object, small pole on top of water tower. Azimuth of Reference Object 13° 58′·6. Surface in immediate vicinity level and open. A small creek flows through a valley, the sides of which rise about one hundred and fifty feet above the water. Although there is not much rock showing in the valley bottom, still the entire district has rock foundation, never very deep below the surface. The rock, however, did not appear to affect the needle.

Chapleau, Ont.—Occupied July 9 to July 13, 1907. Latitude 47° 49′·6. Longitude 83° 27′·0 (from data supplied). Station a relocation of the Carnegie Institution station, occupied October 10, 1906. Reference Object, flag pole on Algoma hotel. Azimuth of Reference Object 252° 33′·9 (from data supplied). The surface con-

ditions at this station are apparently quite favourable, subject to the general comment that the entire district is underlaid by rock, never deep below the surface. On trial, however, portions of this rock did not affect the needle.

On the afternoon and evening of the 10th and the morning of the 11th, the declination needle behaved rather unsteadily, which may be accounted for by the fact that a brilliant display of aurora took place on the evening of the 10th.

Station.	Longitude	Latitude.	Date.	L. M. T.	Declination mean of elongation.	Difference E and W elongation.	Date.	L.M.T.	Dip.	Date.	L.M.T.	Hor. intensity C. G. S. Units.	Total intensity C. G. S. Units.
		′	1907	a.m. p.m. h. m. h. m.	′	′	1907	h. m.	′	1907	h. m.		
*Sydney	60 12·0	46 06·7	Oct. 31	7 45, 1 00	25 27·7	08·5	Oct. 30	10 46	74 16·8	Nov. 1	10 13	0·1563	0·5768
			Nov. 1	7 40, 1 05	25 29·3	10·8							
			" 2	7 45, 2 00	25 26·8	09·1							
Mulgrave	61 22·5	45 35·1	Nov. 5	8 00, 1 40	24 13·0	15·4	Nov. 5	10 00	73 53·6	Nov. 6	10 14	0·1611	0·5807
			" 6	7 40, 12 55	24 13·4	09·2							
Antigonish	61 59·2	45 35·6	Nov. 8	7 40, 1 10	23 25·4	14·0	Nov. 9	9 56	74 17·9	Nov. 8	10 25	0·1596	0·5899
Pictou	62 43·5	45 38·0	Oct. 25-26	7 10, 1 05	23 01·9	11·4	Oct. 25	10 35	74 31·2	Oct. 26	11 11	0·1577	0·5910
			" 26-28	7 40, 1 00	23 01·8	11·8							
Truro	63 15·6	45 20·2	Oct. 23	7 25, 1 00	21 49·4	10·6	Oct. 23	11 22	73 52·5	Oct. 22	10 41	0·1618	0·5827
			" 24	7 55, 12 55	21 52·0	12·5							
Pugwash	63 40·5	45 50·2	Oct. 19	7 35, 1 10	22 39·5	07·9	Oct. 20	11 33	74 48·8	Oct. 19	12 31	0·1544	0·5895
			" 21	7 10, 1 05	22 38·5	14·4							
Shediac	64 31·7	46 12·1	Oct. 17	7 00, 1 30	22 45·8	13·4	Oct. 17	9 26	75 03·5	Oct. 17	10 56	0·1520	0·5894
Moncton	64 47·0	46 06·9	Oct. 14-15	7 10, 1 10	22 14·9	21·1	" 14	3 12	75 07·8	Oct. 15	10 34	0·1515	0·5903
			" 15-16	7 30, 1 05	22 15·0	19·5							
Richibucto	64 51·7	46 40·6	Nov. 13	7 25, 1 05	22 36·3	12·4	Nov. 13	2 30	75 37·1	Nov. 13	11 24	0·1478	0·5960
Newcastle	65 33·0	46 58·2	Nov. 15	7 05, 1 10	22 47·5	12·9	Nov. 16	10 06	75 36·2	Nov. 15	10 20	0·1455	0·5892
			" 16	7 10, 1 10	22 47·3	07·2							
Bathurst	65 39·0	47 37·5	Nov. 18-19	6 55, 1 25	23 41·15	11·4	Nov. 19	9 42	76 01·8	Nov. 20	10 35	0·1431	0·5914
			" 19-20	7 45, 1 05	23 37·7	7·2	" 19	3 00	76 03·1				
Mispec	65 59·0	45 13·3	Oct. 10	6 50, 1 35	20 03·3	14·2	Oct. 10	2 31	75 06·4				
			" 11	6 45, 1 00	20 04·3	13·6							
St. John	66 00·7	45 16·8	Oct. 2	8 50, 12 35	20 11·0	07·9	Oct. 2	10 26	74 25·1	Oct. 4	10 36	0·1592	0·5926
			" 3	8 10, 1 35	20 10·6	07·9	" 3	9 46	74 21·5				
Matapedia	66 55·8	47 56·5	Nov. 21-22	7 25, 12 35	22 53·1	02·9	Nov. 22	9 52	76 36·4	Nov. 23	11 41	0·1387	0·5981
			" 22-23	6 30, 12 20	22 53·6	14·8	" 23	9 42	76 35·8				
							" 24	9 39	76 33·8				
Megantic	70 53·2	45 34·4	Sept. 20	7 35, 12 25	16 34·4	16·3	Sept. 20	10 04	75 40·6	Sept. 21	11 17	0·1498	0·6056
			" 21	7 46, 12 56	16 34·3	13·7							
			" 23	7 41, 12 16	16 31·0	13·3							
Tring Jct	71 00·0	46 15·5	Sept. 26	7 05, 1 35	17 21·5	21·1	Sept. 26	3 03	76 06·2	Sept. 27	3 24	0·1462	0·6094
			" 27	7 30, 1 30	17 23·1	21·9	" 27	10 03	76 07·3				
Sherbrooke	71 56·2	45 23·9	Sept. 14	7 32, 1 22	15 55·4	29·6	Sept. 14	10 26	75 27·3	Sept. 18	1 05	0·1512	0·6018
			" 16	7 22, 12 47	16 02·8	24·6	" 16	10 34	75 26·1				
			" 17	8 02, 12 47	16 01·2	43·0							
			" 18	7 27, 12 02	16 00·1	19·0							

Farnham. .	73 01·5	45 16·1	Sept. 9....	7 00, 12 55	15 13·0	22·0	Sept. 9....	2 28	75 19·0				
			" 11.....	7 50, 12 50	15 11·8	22·6	" 10.	10 10	75 21·2	Sept. 12.	2 51*	0·1540	0·6095
Brockville. .	75 40·7	44 35·9	Sept. 2......	7 00, 1 35	10 34·1	16·9	Sept. 3....	9 43	75 03·6	Sept. 4..	1 08	0·1577	0·6118
			" 3......	6 45, 1 45	10 34·2	17·1							
Ottawa.	75 42·9	45 23·6	June 3......	7 05, 1 20	12 36·5	......	June 3..	10 25	75 41·2	June 7....	12 46	0·1505	0·6086
Kingston, R.M.C	76 28·2	44 13·8	Aug. 20.....	8 10, 2 25	36 44·5	11·1	Aug. 20..	10 10	73 27·3	Aug. 21	1 11	0·1708	0·5998
			" 21.. ..	7 35, 1 25	36 48·4	18·4							
Kingston Jct..	76 28·0	41 15·2	Aug. 27.....	7 40, 12 55	14 17·4	29·9	Aug. 27 .	10 31	74 57·8	Aug. 28 ..	12 39	0·1613	0·6219
			" 28....	7 05, 1 10	14 16·4	13·7							
Kingston Barracks	76 29·2	44 13·0	Aug. 25.....	7 45, 1 10	30 07·4	16·2	Aug. 25 ..	3 00	74 37·3				
Sharbot Lake..	76 41·2	44 46·4	Aug. 16.....	8 25, 12 40	11 28·7	07·4	Aug. 13 .	2 48	74 51·5	Aug. 16	4 05	0·1608	0·6173
							" 14	2 22	74 53·1				
							" 16 .	9 55	74 55·2				
							" 16 .	2 16	74 54·1				
Pembroke. .	77 07·5	45 49·3	July 27. ...	7 22, 1 37	10 22·2	24·2	July 26. .	3 45	76 13·0	July 27.	1 10	0·1476	0·6182
			" 28.. .	6 52, 1 32	10 11·2	11·8	" 28...	10 47	76 12·7				
							" 28...	3 50	76 07·8				
Barry Bay....	77 40·3	45 28·8	Aug. 9......	7 00, 2 00	08 46·3	07·8	Aug. 9....	9 53	75 57·5	Aug. 9. ..	4 15	0·1501	0·6197
							" 9....	2 55	75 54·2				
Mattawa.....	78 41·0	46 19·7	July 23.....	7 40, 1 35	08 43·3	17·2	July 23...	9 37	76 42·1	July 23...	2 [illegible]	0·1429	0·6205
			" 24.....	7 15, 1 10	08 45·4	21·4	" 24.	10 47	76 40·4				
Joe Lake ...	78 46·5	45 35·2	Aug. 6.. ..	7 15, 1 00	07 32·5	17·1	Aug. 6.	10 00	75 57·6	Aug. 6. .	1 17	0·1525	0·6281
			" 7......	7 40, 12 45	07 28·8	14·0	" 6. .	3 59	75 56·5				
North Bay....	79 24·7	46 18·3	July 19.....	7 30, 1 00	08 57·2	13·6	July 18.	1 35	76 35·7	July 19.	12 44	0·1433	0·6182
			" 20....	7 15, 12 35	08 54·0	20·2							
Rose Point..	80 02·3	45 19·1	Aug. 2. ..	8 10, 2 25	06 47·8	12·6	July 31.	2 36	75 39·7	Aug. 3. .	2 20	0·1525	0·6588
			" 3.....	6 50, 1 45	06 49·7	08·1	Aug. 1....	9 40	75 32·5				
			" 4. ...	6 30, 1 45	06 49·9	06·2	" 2....	9 30	75 38·8				
							" 2.. .	3 50	75 33·4				
							" 4..	10 22	75 36·3				
Sudbury	81 00·0	46 29·0	July 16.	7 40, 2 20	06 57·1	18·2	July 15...	10 14	76 35·4	July 17...	1 35	0·1451	0·6254
			" 17.....	7 00, 1 25	06 52·8	21·6	" 15..	2 48	76 35·1				
Chapleau...	83 27·0	47 49·6	July 13. ...	7 40, 1 55	03 47·0	32·8	July 11..	9 07	77 57·9	July 12...	11 32	0·1321	0·6304
							" 11.	5 27	77 50·4				

* Tesdorpf Magnetometer, No. 1977.

Station.	Longitude		Latitude		Date	Declination		Dip		Hor. Intensity	Total Intensity
	°	′	°	′	1907	°	′	°	′		
*Sydney	60	12·0	46	06·7	Oct. 30-31, Nov. 1-2	25	27·9	74	16·8	0·1563	0·5768
Mulgrave	61	22·5	45	35·1	Nov. 5-6	24	13·2	73	53·6	0·1611	0·5807
Antigonish	61	59·2	45	35.6	Nov. 8-9	23	25·4	74	17·9	0·1596	0·5899
Picton	62	43·5	45	38·0	Oct. 25-26-28	23	01·9	74	31·2	0·1577	0·5910
Truro	63	15·0	45	20·2	Oct. 22-23-24	21	50·7	73	52·5	0·1618	0·5827
Pugwash	63	40·5	45	50·2	Oct. 19-20-21	22	39·0	74	48·8	0·1544	0·5895
Shediac	64	31·7	46	12·1	Oct. 17	22	45·8	75	03·5	0·1520	0·5894
Moncton	64	47·0	46	06·9	Oct. 14-15-16	22	15·0	75	07·8	0·1515	0·5903
Richibucto	64	51·7	46	40·6	Nov. 13	22	36·3	75	37·1	0·1478	0·5960
Newcastle	65	33·0	46	58·2	Nov. 15-16	22	47·4	75	36·2	0·1465	0·5892
Bathurst	65	39·0	47	37·5	Nov. 18-19-20	23	39·4	76	03·9	0·1431	0·5944
Mispec	65	59·0	45	13·3	Oct. 10-11	20	03·8	75	06·4		
St. John	66	00·7	45	16·8	Oct. 2-3-4	20	10·8	74	24·8	0·1592	0·5926
Matapedia	66	55·8	47	56·5	Nov. 21-22-23-24	22	53·3	76	35·3	0·1387	0·5981
Megantic	70	53·2	45	34·4	Sept. 20-21-23-24	16	33·2	75	40·6	0·1498	0·6056
Tring Jct	71	00·0	46	15·5	Sept. 26-27	17	22·2	76	06·7	0·1462	0·6094
Sherbrooke	71	56·2	45	23·9	Sept. 14-16-17-18	15	59·9	75	26·7	0·1512	0·6018
Farnham	73	01·5	45	16·1	Sept. 9-10-11	15	12·4	75	20·1	0·1540	0·6095
Brockville	75	40·7	44	35·9	Sept. 2-3-4	10	34·2	75	03·6	0·1577	0·6118
Ottawa	75	42·9	45	23·6	June 3	12	36·5	75	41·2	0·1505	0·6086
Kingston R.M.C.	76	28·2	44	13·8	Aug. 20-21	36	46·4	73	27·3	0·1708	0·5998
Kingston, Jct	76	28·0	44	15·2	Aug. 27-28	14	16·9	74	57·8	0·1613	0·6219
Kingston Bar'cks	76	29·2	44	13·0	Aug. 25	30	07·4	74	37·3		
Sharbot Lake	76	41·2	44	46·4	Aug. 13-16	11	28·7	74	54·6	0·1608	0·6173
Pembroke	77	07·5	45	49·3	July 26-27-28	10	16·7	76	11·2	0·1476	0·6182
Barry Bay	77	40·3	45	28·8	Aug. 9	08	46·3	75	53·9	0·1501	0·6197
Mattawa	78	41·0	46	19·7	July 23-24	08	44·3	76	41·2	0·1429	0·6205
Joe Lake	78	46·5	45	35·2	Aug. 6-7	07	30·6	75	56·0	0·1525	0·6281
North Bay	79	24·7	46	18·3	July 18-19-20	08	55·6	76	35·7	0·1433	0·6182
Rose Point	80	02·3	45	19·1	July 31, Aug. 1-2-3-4	06	49·1	75	36·1	0·1525	0·6588
Sudbury	81	00·0	46	29·0	July 15-16-17	06	54·9	76	35.2	0·1451	0·6254
Chapleau	83	27·0	47	49·6	July 11-12-13	03	47·0	77	54·1	0·1321	0·6304

*Tesdorpf Magnetometer, No. 1977.

GRAVITY.

Unfortunately the new sidereal chronometers ordered were not received in time for undertaking gravity work during the past season. The chronometers of the observatory heretofore available were required for urgent longitude determinations in various parts of the Dominion.

I have the honour to be, sir,

Your obedient servant,

OTTO KLOTZ.

OTTAWA S

Fig 5—SEISMOGR

OGRAM AT OTTAWA

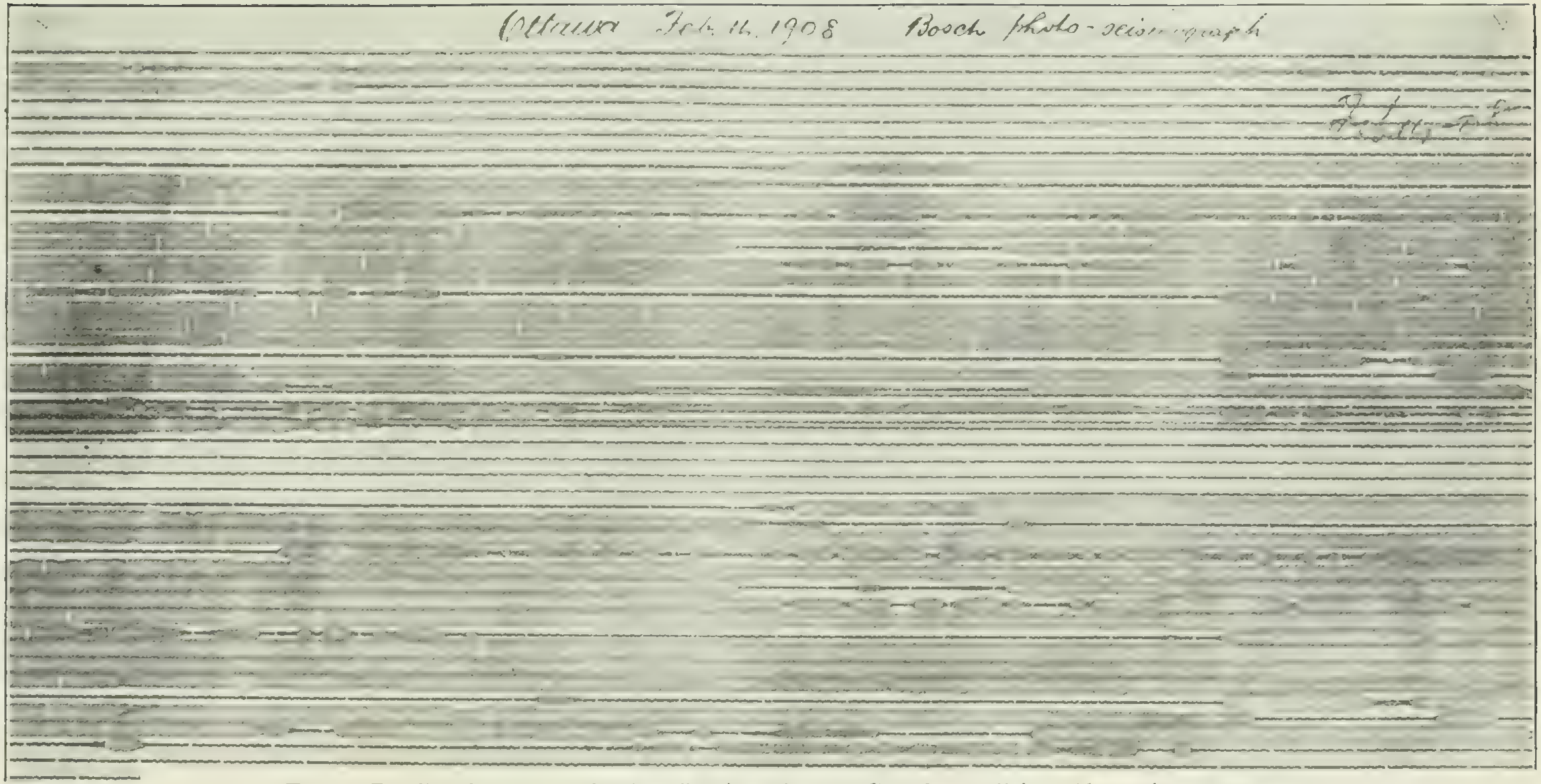


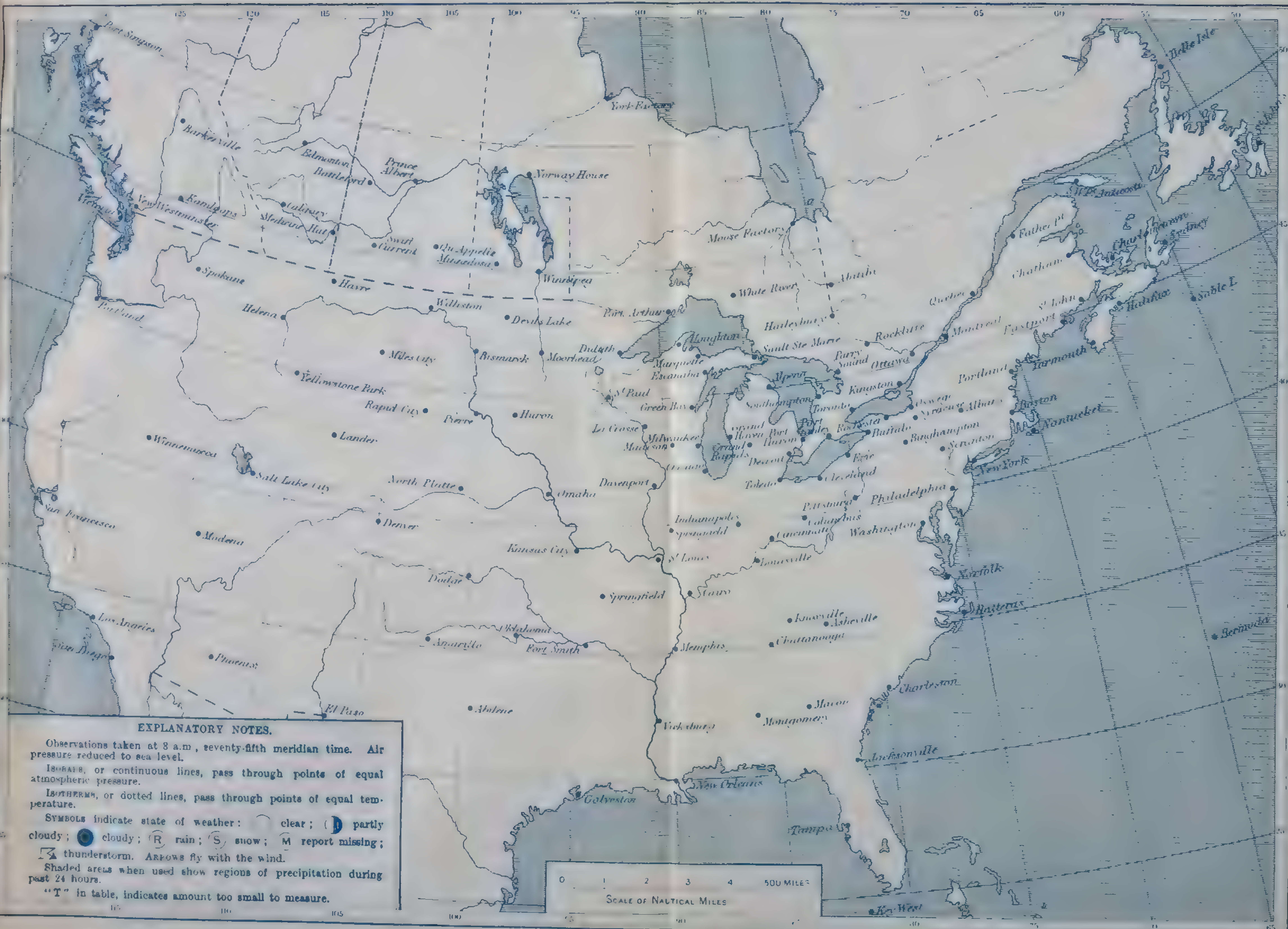
FIG. 1.—Peculiar phenomenon showing vibrations of new 23 Cm. filament light. Alternating current.

WEATHER MAP

METEOROLOGICAL SERVICE, DOMINION OF CANADA.

R. F. STUPART, Director.

Published by authority of the Department of Marine and Fisheries.



To accompany Report of Dr Klotz 1903

APPENDIX 2.

REPORT OF THE CHIEF ASTRONOMER, 1908.

ASTROPHYSICAL WORK

BY

J. S. PLASKETT, B.A.

CONTENTS.

Appendix C.—R. M. Motherwell.

Appendix D.—Ralph E. DeLury.

Appendix E.—W. M. Tobey.

ILLUSTRATIONS.

APPENDIX 2.

ASTROPHYSICAL WORK BY J. S. PLASKETT, B.A.

OTTAWA, ONT., March 31, 1908.

W. F. KING, Esq., B.A., LL.D.,
Chief Astronomer,
Department of the Interior,
Ottawa.

SIR,—I have the honour to submit the following report of the work carried on by me and under my direction during the past year.

Owing to the change in the date of presenting the report, it deals with only seven or eight months' work and consequently will not be found to cover so much ground as formerly. I think, however, it will indicate satisfactory progress in every department under my charge. Some of them are as yet only in the organization stage, and not much actual work accomplished can yet be reported, although very satisfactory progress in the preparatory stages has been made.

I wish particularly to draw to your attention the very efficient work that has been accomplished by my three assistants, Messrs. Harper, DeLury and Motherwell, in their various lines. I can speak in the very highest terms, not only of their ability and energy, but also of their conscientious attention to their duties.

I propose to present to you here a short summary of the principal pieces of work carried on, each being presented below in detail, and where possible over the signature of the officer responsible for it.

The principal work, as previously, has been the determination of the line of sight velocities of stars by the spectroscope, chiefly of spectroscopic binaries for the determination of their orbits. The new combined three prism and single prism spectrograph, which was fully described in last year's report, has performed very satisfactorily. Some minor improvements, altogether outside the spectrograph proper, however, have been added and it is doing and has done excellent work. Our experience has shown, however, that separate instruments would be much more useful, and a new single prism spectrograph has been designed, the optical parts have been ordered by you, and the mechanical parts will be constructed in the workshop as soon as possible.

Of the dozen spectroscopic binaries under observation two, ι Orionis and ψ Orionis have been completed, and two, θ Aquilæ and η Virginis, have had provisional elements determined. Work on several others is well under way, and it is hoped that some of them will shortly be completed. It may be stated in this connection that considerable work may be done on spectroscopic binaries without it being found possible in some cases to obtain any definite result. This is due to a small range of velocity combined with a poor quality of spectrum for measurement, so that the periodic effect is masked by the large accidental errors of observation. If the period could be obtained in such a case it is possible, after observations over several periods had been combined into phases, exactly as has been done in ι Orionis, described below, that approximate elements could be determined; but unless the period can be obtained no such combination of observations is possible. For the above reasons observations and measurements on one binary o Andromedae have been discontinued.

It gives me pleasure in connection with the work on radial velocities to make especial mention of the very efficient manner in which Mr. Harper has assisted in this

work. Besides doing the lion's share of the measuring and reduction of spectrograms, he has equally divided with myself the work of observation. Moreover, it is not only the quantity of the work, but the quality that deserves mention. His measures are very careful and accurate, and his work throughout thoroughly dependable. He has presented a report of his work on two spectroscopic binaries, θ Aquilæ and η Virginis, in appendices A and B below. His measures on other uncompleted binaries and on ι Orionis, which is discussed by myself, have probably occupied considerably more time than the work reported.

Mr. Westland, who since November has efficiently assisted Mr. Harper and myself in the work of measuring and reducing star spectra, will be leaving for the field in a short time. In order to have the measuring and reduction keep pace with the observing, two capable assistants are required. It is desirable to obtain assistants who will be permanently engaged in this work, as considerable training and experience is required before reliable measurements can be obtained. As soon as suitable men can be obtained I would respectfully urge their appointment.

The Hartmann-Zeiss Spectro-Comparator, which you ordered upon my representation a year ago, has only quite recently arrived. It is a very workmanlike instrument and, so far as our tests have gone, gives every promise of doing very accurate and satisfactory work. It is evident, however, that its special use will be in spectra of the solar and related types. Spectra of the early hydrogen and helium types will preferably, I believe, be measured as previously.

I am gratified to report that, although the new correcting lens when first received did not give much better images than the old, a refiguring of its surface enabled it to produce practically perfect results. Not only is the image free from aberration, ensuring uniform illumination of camera and collimator lenses and consequent freedom from chance of systematic displacement of the lines, but its smallness and perfection ensure the greatest possible slit transmission, and result in a considerable diminution in the required exposure time, estimated as at least 30 per cent. We may therefore consider the time and energy required to make this improvement to be well spent. A full report of the tests of the new corrector, both before and after refiguring, with a description of a number of experiments on the actual dimensions of the star image and the conclusions derived therefrom is given below.

In my last report I gave an account of an investigation undertaken for determining the effect of increasing the slit width of a spectrograph on the accidental errors of measurement. This showed that the errors by no means increased proportionally with the increase of slit width, although scarcely sufficient data were obtained to give any definitive results. This investigation has been continued this year, using three different dispersions available with the new spectrograph, and some very interesting as well as useful results obtained. They show that with a single prism instrument on early type stars the slit may be opened to 0·051mm without any marked increase of accidental or systematic error, while with a three prism spectrograph this width may be increased to 0·076mm without much increasing the error of measurement. Details of the measurements and conclusions are given in full below.

My interest in camera lenses for spectrographs has not diminished, although I am unable to report much advance beyond what was accomplished last year. I there described the excellent performance of the Brashear single material for single prism and the Hartmann-Zeiss 'Chromat' for three-prism work. These are both however, of about 525mm focus and 45mm aperture. Lenses of shorter focus with the same aperture offer greater difficulties in the design and construction, and Zeiss, in reply to a request to construct such a lens, states that the 'Chromat' cannot be successfully made of larger angular aperture than already supplied. They suggest a trial of their Tessar photographic objective, and, by the kindness of Mr. De Courcey Topley, one was obtained for testing from the Bausch and Lomb Optical Co., of 12 inches focus and about 2 inches aperture. A preliminary test of this lens showed very promising

results. The definition is very good and the field very nearly flat. It looks as if it would make a satisfactory objective for spectrographic work. Brashear has made three new lenses of the 'Chromat' type of different materials which have just been received and await testing. They are of somewhat shorter focus than the Zeiss 'Chromat,' and the result of the test should prove interesting. The special Ross Homocentric lens of 10 inches focus, which, according to the makers claim, should have fulfilled the desired requirements, proved a disappointment as, although the definition was good, the field had such strong curvature as to render it quite useless for spectrographic work. At their request it has been returned to them for improvement and it is hoped that it may be made satisfactory.

A good start at micrometric work has been made by Mr. Motherwell, who has made a number of measures of the position angle and distance of some selected double stars. The occultations of stars by the moon visible at Ottawa have, whenever the weather permitted, also been observed and their times of immersion and emersion carefully determined. He has compiled a summary of these measurements and observations, which is given below in appendix C. He has spent considerable time in investigating the field of the Brashear photographic doublet of 8 inches aperture and 42 inches focus by the Hartmann method of extra-focal exposures. The investigation shows that the lens possesses very considerable over-correction for spherical aberration, more than sufficient to account for the large images given. The field, however, is flat and, if the aberration can be overcome without affecting the curvature of field, the lens will be unsurpassed.

I had hoped to be able to report that work with the coelostat telescope had been begun, but, owing to the delay in getting the building ready, this has not been possible and nothing more can now be done until spring. The opening between the tunnel and the laboratory in the basement was not completed in time, and, to prevent freezing up, both ends had to be blocked preventing the installation of the solar spectroscope. The mechanism for the telescope is completed and in place. Dr. DeLury will shortly be engaged in setting up, adjusting and testing the 23-foot plane grating spectroscope for use with the coelostat so that, as soon as possible, everything may be placed in working order and actual observation begun.

On every clear day photographs of the solar surface on a scale of about 7½ inches to the sun's diameter have been obtained for a record of the spots, but no plates have yet been measured. The concave grating spectroscope, at present installed on the midway floor, was very carefully adjusted by Dr. DeLury and has been used by him in obtaining photographs of the spark spectrum of the iron-vanadium alloy used by us as the comparison spectrum in stellar spectroscopy. This is a necessary piece of work as many of the lines used are blends of iron and vanadium and their wave lengths can only be accurately determined in this way. These plates have been measured and reduced to wave lengths in the hope of obtaining a consistent set of wave lengths of both elements for the above purpose. Owing, however, to the want of a suitable measuring machine the values obtained have not been entirely satisfactory and a remeasurement will be undertaken as soon as possible. A description of the work done and the results obtained by Dr. DeLury is given below in appendix D.

A small chemical laboratory which will be of service in astrophysical investigations, in silvering the mirrors of the coelostat and for numerous other purposes has been fitted up by Dr. DeLury in the room in the basement beside the solar research laboratory.

As mentioned in the last report, a polarizing photometer, modelled somewhat after the Zöllner form, was constructed in the workshop last summer, and Mr. Tobey has been using it in the measurement of the magnitudes of stars. Up to the present, most of his time has been spent in obtaining the scale of the instrument. The exceptionally bad weather during the past winter has prevented much astronomical work of any

nature being done and photometry has suffered as well as other lines. A short report by Mr. Tobey on his work is given in appendix E.

The workshop has, as last year, proved its indispensibility in the work of our observatory and in the Geodetic and other surveys under your direction. The mechanician, Mr. Mackey, has been kept very busy during the whole year. It has indeed been impossible for him to do all the work required. This work is growing so rapidly both in the Astronomical and Astrophysical divisions, and in the Boundary and Geodetic surveys, that the new construction and repairs necessary is entirely beyond the capacity of one man. As all the work can be done much better and cheaper in our own workshop, and as much of the experimental work, which requires supervision by the designer and user, can not be done elsewhere, the need of an assistant was strongly felt. I have to express my obligation to you for your readiness in recognizing this need and taking steps to supply it.

Since my last report the workshop has been removed to the southwest corner of the basement. The light in this room is much better and its larger size has allowed the machines to be arranged to much better advantage, enabling both the quantity and quality of the output to be enhanced. Much of the time of Mr. Mackey has been spent in small repairs, but besides these the travelling wire micrometer for Cooke 1 has been completed, the polarizing photometer has been made and several attachments for convenience in using the spectrograph have been applied.

With your approval the charge of the instruments, so far as the bookkeeping is concerned, has been entrusted to Mr. Motherwell who has carefully kept account of them, leaving only the general supervision and the question of repairs in my care. The number of field instruments in store and in use has rapidly increased of late and their proper looking after requires considerable time.

The interest of the public, as shown by their attendance at the Saturday evening open nights, has continued unabated and our effort to increase and specialize this interest by the formation of an astronomical society in Ottawa has met with a gratifying response. Such a society is a useful adjunct to our work, not only by increasing the interest of the people in astronomical matters, but also in giving them correct ideas of the value and work of our observatory. The papers read at the meetings, especially the afternoon or 'technical' meetings, have been of a high class, while the matter presented in several of them has been the product of original investigation and research of value and has formed distinct contributions to science. To say nothing of the encouragement to original work such papers are of general educative value giving each of us a better knowledge of the work being carried on by our colleagues, while they are of special service to those who prepare them, necessarily entailing a thorough mastery of main principles and details not likely otherwise to be obtained.

The following papers bearing on the work of the Astrophysical division have been published since the date of the last report:—

1. The Star Image in Spectrographic Work, by J. S. Plaskett, Journal of the Royal Astronomical Society of Canada, Vol. 1, No. 5, p. 297.

2. Preliminary Orbit of θ Aquilæ by W. E. Harper, Journal of the Royal Astronomical Society of Canada, Vol. 1, No. 6, p. 357.

3. The Star Image in Spectrographic Work, II., by J. S. Plaskett, Astrophysical Journal, Vol. XXVII., p. 139, March, 1908.

4. Orbit of η Virginis by W. E. Harper, Astrophysical Journal, Vol. XXVII., p. 160, March, 1908.

5. A Transportable Form of Standard Cell, by R. E. DeLury, Physical Review, Vol. XXV., p. 492, 1907.

6. Device for preventing bumping in Mercury Air Pumps, by R. E. DeLury, Physical Review, Vol. XXV., p. 495, 1907.

7. The Spectroscopic Binary ι Orionis, by J. S. Plaskett and W. E. Harper will appear in Astrophysical Journal in April.

8. The Aberrations of a Stellar Camera Objective, by R. M. Motherwell. Thesis presented for M.A. degree at University of Toronto, March 28, 1908.

The matter in the above papers treating on spectrographic work is presented in a somewhat different form in this report.

Before entering into the details of the work, however, I wish to express my deep appreciation of the hearty support and efficient help you have given me in the undertakings completed or in hand. Without such help and encouragement, so much progress would certainly not have been reported.

THE SPECTROGRAPH.

The new Ottawa spectrograph has been used exclusively in the determination of radial velocities since its completion last summer. This instrument was fully illustrated and described in last year's report, and I have little to add in this place. Further experience in its use has confirmed the good opinion formed of its performance, and no changes have been made in the spectrograph proper. Some difficulty was at first experienced in the temperature regulation, a gradual lowering of the temperature in the prism box of about 0·1°C. per hour occurring as the room temperature kept falling. The heating coils were at first placed only in the lower portion of the case as advocated by Hartmann and, although the temperature around the contact thermometers must have remained constant, the increased radiation, as the difference between inside and outside temperatures increased, would lower the temperature of the upper part of the case and this would be transmitted by conduction through the metal parts to the prism box. In consequence, additional heating coils were placed up the sides of the box so as to practically cover the whole inside surface of the case and the difficulty then disappeared. There is, naturally enough, if the temperature of the case is set only slightly above the outside temperature, a slight drop in the prism box temperature if the room temperature falls two or three degrees; but, if the dome be opened about half an hour before sunset, this drop takes place considerably before observing begins and is not likely to produce any error in observations made an hour after it occurs. The only possible difficulty or cause of error that may arise is due to the proximity of the coils on the sides of the case to parts of the tubular truss frame, especially to the diagonal tubular truss connecting the outer end of prism box to the upper ring casting. Any long continuance of the heating current would probably raise their temperature and displace slightly the position of the spectral lines. Any error from this cause is however, fairly well guarded against by, first the intermittent action of the automatic heat regulation, the heat being turned on and off generally two or three times a minute and consequently not having time to affect such a mass of metal, and secondly by covering the tubes with a non-conducting layer of felt which must so smooth down the irregularities of the regulation as to ensure constant temperature in the truss. As soon as opportunity offers, however, this possible source of error will be guarded against either by some means of air stirring or by increasing the distance between the coils and the tubes.

The 10,000 volt transformer ordered for producing the comparison spark was received in the fall and, as soon as possible, the connections were altered to allow its use instead of the induction coil. The secondary wires from the induction coil already ran up the column across to the tube of the telescope and then down it to the comparison apparatus, thus avoiding any wires across the floor. But it was necessary

when putting on the comparison spark to move from the guiding eye-piece to the switch of the induction coil. When the transformer was substituted for the coil, the connections were so arranged that the spark could be turned on and off by a switch on the telescope tube directly above the eye-piece. The alternating current lighting circuit is led to three receptacles attached to the south side of the telescope column. Two of these are used for movable lights with long attaching cords while the third feeds the transformer and the heating coils of the temperature case. Wires lead from the two sides of this receptacle to a double-pole knife-edge switch below the relay box. From the other sides of this switch, one proceeds direct to one terminal of the transformer primary while the other runs up the telescope column through a variable resistance of six 32 c.p. lamps, situated just above the relay box, of which one only or two or more in multiple as required may be placed in the circuit. This wire then proceeds, beside the heating and secondary wires, down the tube to one terminal of a single pole switch near the eye end, while a wire from the other terminal follows the same course past the bank of lamps direct to the other primary terminal of the transformer. A variable capacity is placed in multiple across the secondary terminals, and a variable self-induction in series between one of the secondary and the spark terminals. The intensity and character of the spark may be varied between wide limits by changing the intensity of current through the primary by means of the lamp resistance, or by changing the capacity or self induction or both in the secondary circuit. Moreover, when once set, the spark remains nearly constant, much more so than is the case with an induction coil. Transformer, capacity, and self induction are permanently attached to the column as shown in fig. 1, which shows the spectrograph ready for use, and are always out of the way. After throwing in the double pole switch the spark can be controlled by the single pole on the tube. The ease of applying the comparison enables it to be used much more frequently during the exposure on the star, thus lessening the chance of systematic error.

Besides the change in the heating coils and in the production of the comparison spark, knurled thumb screws have been substituted for the ordinary machine screws first used in attaching the temperature case. Similarly where, before, wires had to be attached to binding posts at the lower part of the case whenever change was made from single to three prism form or vice versa, now all are attached to plugs which simply shove into jacks. Moreover, as in three prism work the Hartmann-Zeiss Chromat camera objective is used, and in single prism the Hastings-Brashear single material, a separate camera was made for each to prevent dismemberment and change of adjustment when changing from high to low dispersion or vice versa. The purpose of these improvements was to shorten the time required to make the change from one form to another, which frequently requires to be performed, often both single and three prisms being required on the same night. This change can now be entirely made in 15 minutes and if this time were the only consideration it would not amount to very much in a night's work. Unfortunately temperature difficulties arise in such a case and, although they are much diminished by the provision of an automatically controlled constant temperature box for holding the prism train or single prism with attached camera, which is seen on the stand to the left of fig. 1, there is still some uncertainty in regard to the temperature of the prisms. This consideration led to the decision, to which you readily agreed, to make a separate single prism spectrograph with temperature case and attaching stand complete, provide a separate relay box and have both instruments always maintained at constant temperature ready for instant change. In such a case the change would not occupy five minutes and the temperature need not be disturbed in the slightest, as the set of plugs on the telescope could be substituted for those belonging to the separate relay box in a few seconds.

The information gained in regard to the character of the star image from the experiments carried on after the new correcting lens had been installed, which are described below, showed that the effective star disc is practically never less than

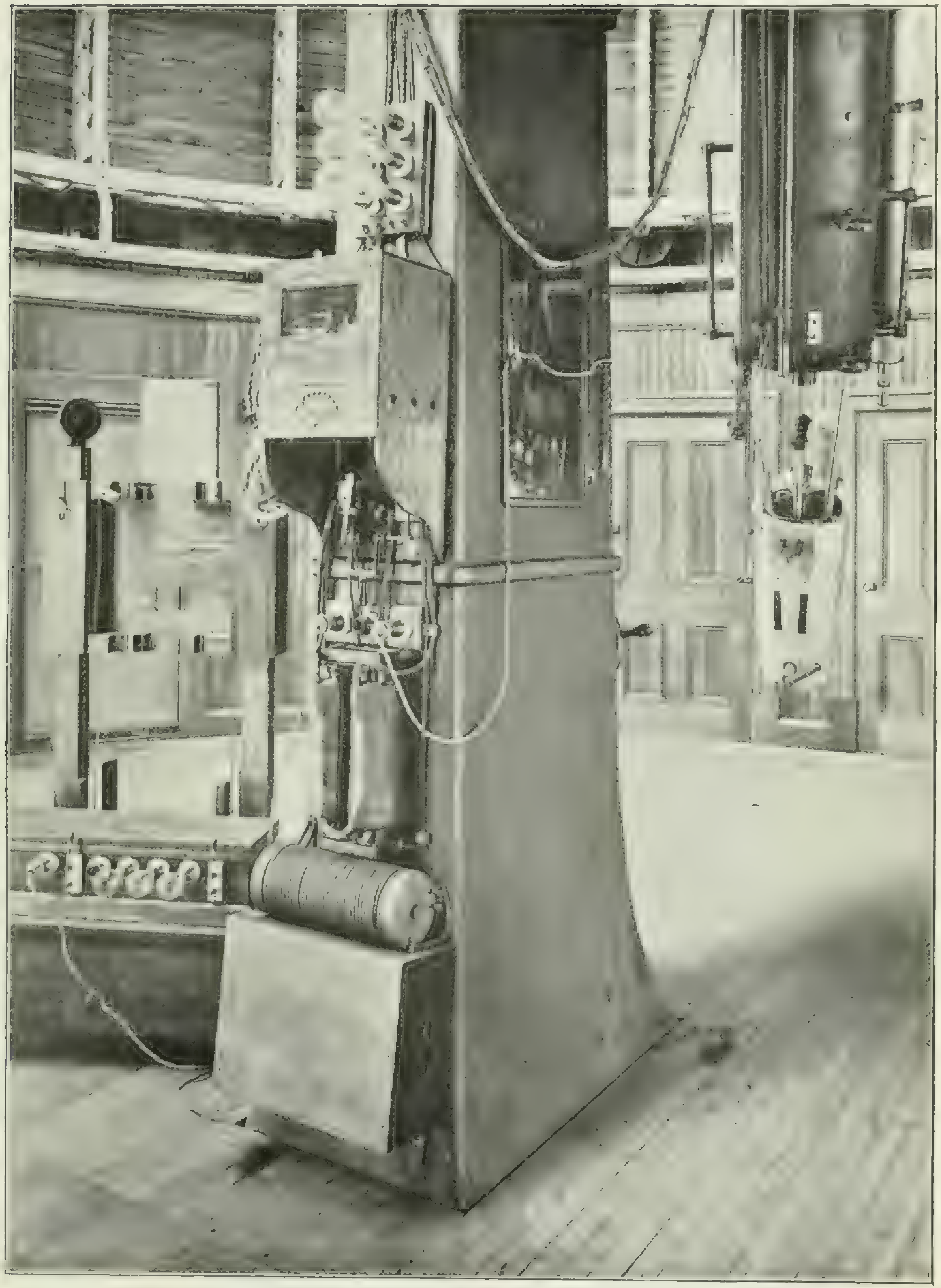


FIG. 1.—Transformer, Capacity and Self-induction.

2 secs. of arc in diameter, equivalent to 0·055mm at the focus of our 15 inch, and generally much greater, frequently 0·075mm. In order to make use of the greater part of the starlight collected by the objective, we must be able to use a slit at least 0·05mm wide in our spectrograph, and, in order to use this width without too much loss of purity or loss of definition of the lines, it is necessary to use a longer collimator, consequently of larger aperture, with a larger prism. In the present spectrograph, used with single prism, the practical limit of slit width appears to be about 0·040mm. If the slit is made wider than this, the lines both star and comparison appear wide and diffuse. However, in the case of early type stars, the experiments on the relative accuracy of different slit widths show that the slit can be made 0·05mm without much loss of accuracy, but the spectra look poor, the lines, especially comparison, appearing diffuse. The camera is of the same focal length as the collimator, 525mm, so that the minimum width of lines is the width of slit. If the length of collimator were increased or the length of camera decreased, leaving all questions of resolution and purity, which have little bearing on early type spectra with single lines, aside, then the minimum width of line would be decreased in like ratio and consequently the slit width could be correspondingly increased without making the lines more diffuse. Decrease in camera length means decrease of linear dispersion, while increase in collimator length means a larger prism with difficulties in homogeneity and the covering power of the camera objectives. Prof. Frost's experience with large prisms shows the possibility of obtaining good results with 51mm aperture and, as the methods of annealing are certainly no worse now, the chances of homogeneous glass in a prism of that size seem good. It is proposed therefore to make the aperture of the collimator of the new single prism instrument 2 inches (51mms) which makes the focal length 30 inches (762mm). The camera is to be of focal length 18 inches (457mm) and for the same minimum width of line, as is given by slit 0·040 with the present instrument, the slit width may be increased to $^{30}/_{18} + 0{\cdot}40 = 0{\cdot}067$mm, nearly 70 per cent. While the purity of spectrum thereby produced would be only 5 per cent less than with the present instrument.

The experiments on the dimensions of the star image detailed below show that at least 60 per cent more starlight will be transmitted by a slit 0·067 than by a slit 0·040mm. Against this, however, is to be placed the increased absorption of the larger prism. Considering the transmission along the axis of the pencil, the paths through the glass will be about 57 and 39mm respectively. The percentages of $H\gamma$ light transmitted, using Vogel's data* are 70 per cent and 78 per cent, respectively. Thus we obtain, after transmission through the prism, a beam of $H\gamma$ light 44 per cent more intense with the large prism for the same character of spectrum for measurement and only 5 per cent less purity. The linear dispersion is, of course, only $^6/_7$ths of the original and the measures will consequently be that much less accurate. If we were to make the camera of the same focal length, 21 inches (525 mm.), as in the present spectrograph, the slit could be increased to 0·057 mm., giving the same character of spectrum with an increased transmission of star light of nearly 40 per cent. Considering the increased loss by absorption, the beam of $H\gamma$ light after transmission through the large prism would be 25 per cent more intense, while the purity of the resulting spectrum would be nearly 5 per cent greater and the linear dispersion the same.

There is thus considerable gain in the use of the larger prism, sufficient to compensate for the increased size and weight of the spectrograph. The design of the new spectrograph is a somewhat radical departure from that of the previous single prism attachment. As stated in last year's report, flexure was considerable in the single prism instrument owing to the extended form of the truss and its support from one end only. It is proposed in the present design to make the spectrograph proper of

* Astrophysical Journal, V. p. 75.

triangular box form of two triangular steel plates fastened together by cross webs about 3 inches wide. The slit will be at one acute (30°) angle of this triangle, the camera at the other and the prism at the obtuse (120°) angle. This box will be self-contained and be supported in a cradle of angle iron at three points, the pressures on these being equalized by counterbalancing levers. By this means flexure, it is hoped, will be entirely overcome and, as the box will be of compact and symmetrical form, accurate temperature control will offer fewer difficulties than in the present type. I am indebted to a design by Dr. Ralph H. Curtiss for the box form of instrument, but the three point support system is new.

When this new instrument is constructed, the gain in convenience and saving in time will be considerable, and one can then, if desired, change from high to low dispersion or vice versa if only for one star without loss of time or fear of temperature difficulties. There will be a saving in exposure time over the present form of probably 25 per cent and the spectra will undoubtedly be free from displacements of the lines due to flexure, while any temperature effects will be minimized.

The three prism form at present in use gives very satisfactory results, and there does not seem to be any change required in the spectrograph itself. Some improvement in the temperature regulation might be effected by applying a fan or some such device for stirring the air within the case to equalize the temperature throughout and prevent stratification, but such will be difficult to adapt on account of the extra weight and possible vibration.

The Hartmann-Zeiss 'Chromat' camera objective gives an almost absolutely flat field over the whole range of spectrum on the plate $H\beta$ to $H\delta$, or about 8°, which is about three times that usually obtained in spectrographs. Its focus is 525 mm. aperture 45 mm., giving a linear dispersion of 10·1 tenth-metres per mm. at $H\gamma$. With this dispersion, the exposure time required for stars fainter than the fourth magnitude becomes rather long and a shorter focus camera would be very useful. As stated in last year's report, lenses of 375 and 250 mm. focus and 45 mm. aperture were ordered from the John A. Brashear Co., but so far they have not been supplied. One of 375 mm. focus of similar type to the 'Chromat' is completed but it has not yet reached here. A Ross 'Homocentric' lens, which had been kindly loaned by Mr. Topley, gave promising results in the preliminary test and consequently one of 10 ins. focus f5·6, of special construction was ordered from Ross. The lens reached here and was tested some time ago, but the result was disappointing. The definition at the centre of the field was excellent, showing a good correction for spherical aberration, but the field was too strongly curved, falling away from the tangent plane upwards of a millimetre at 4° from the axis. The curvature allowable would not be much more than a tenth of a millimetre, and this is what Ross claimed for the lens. Further tests of the lens showed that if the separation of the two elements was increased by 2⅝ inches, or if the separating mount was made 4⅞ inches long instead of 2¼ inches, the field became very nearly flat. This increased separation, however, increased the focal length about 15 per cent and, what was worse, destroyed the crispness of definition. The lines, especially the intense ones, developed wings to the red side and consequently the value for spectrographic work was lost. The lens was therefore returned to the makers to see if anything could be done in the way of improvement.

An application to Zeiss to supply a 'Chromat' of shorter focus than 525 mm. resulted in the reply that they could not be successfully made of larger angular aperture than the one supplied. They advised the trial of their Tessar lenses of the required focal length.

The loan of a Bausch & Lomb-Zeiss Tessar, Series IIb f6·3 of 12 inches focus was kindly effected for me by the Topley studio and a preliminary trial of this lens has recently been made. Failing a suitable mounting, the lens and the plate holder end of the camera were held in temporary supports to enable the test to be made. The lens gives excellent definition, no sign of the wings shown by the separated Ross being evident. The field, although not so flat as that given by the 'Chromat,' has still at

the margins not more than about a quarter of millimetre curvature. This may possibly be removed by a slight change in the separation of the elements, which will be determined by a further test, but in any case the lens is quite usable over the range required.

This question of suitable camera lenses for spectrographs, lenses which will give accurately measurable spectra over the whole range ordinarily available, $H\beta$ to K in single prism work, and $H\beta$ to $H\delta$ in three prism work, is a very important one, especially in the application of the new method of measurement by the Hartmann Spectro-Comparator. Up to the present the camera lenses ordinarily employed have given a usable field of only about 2½° or in the three prism spectrographs of about 200 tenth-metres, in single prism instruments of about 600 tenth-metres. The Hartmann-Zeiss 'Chromat' was a marked advance over previous objectives for three prism work, giving a flat field over the whole range of photographic spectrum and consequently quadrupling the amount of available material for measurement with the same exposure. The Hastings-Brashear Single Material, which was designed and constructed at my suggestion gives equally good results for single prism work, the field being almost absolutely flat over the whole range of visible spectrum, an actual test having been made from below D to about λ 3800, without any sign of curvature, and consequently allowing accurate measurements to be made over the whole range of star spectrum that may be photographed in one exposure. Both of these objectives, however, have an aperture ratio of about $f/13$ and the former at any rate can not be made of a much greater aperture. It remains to be seen what success will attend the efforts of Messrs. Hastings & Brashear to make shorter focus lenses for three-prism work. Failing these the only hope seems to lie in a photographic or adapted photographic objective for the purpose, and I propose to test every type available.

THE NEW CORRECTING LENS.

In appendix B to my report of last year is given an account of some experiments and measurements determining the aberrations of the original correcting lens and the size and character of the star image given by the system of visual objective with auxiliary photographic corrector. In that appendix I showed that the correcting lens, designed to render our 15-inch visual objective suitable for photographing the spectra of stars, did not give as good an image as it should, that the combination of objective and correcting lens had negative aberration, in other words, that the focus for light coming from the edge of the objective was longer than the focus for light coming from the centre. It was further shown that this was due to the failure of the correcting lens to compensate for the chromatic differences of spherical aberration inherent in the objective. This chromatic difference is a property or defect of all two part objectives of the ordinary glasses and can not be avoided by any combination of curves. Although the objective may be perfectly corrected for spherical aberration with visual light, that is, every zone may bring light to the same focal point, nevertheless, when the same objective is used with blue and violet, or photographic light, it has negative aberration, the edge rays have a longer focus than the central rays, and this is the chromatic difference. Besides changing the form of the colour curve of the objective, bringing the centre of the range of photographically active light, about $H\gamma$, to a minimum focus instead of λ 5600, the correcting lens should also overcome this chromatic difference, so that the resulting combination would be free from aberration at $H\gamma$. As my experiments clearly showed, however, the correcting lens instead of diminishing had slightly increased this aberration and, as a result, the edge rays focussed about 2·5 mm. farther from the objective than the central rays. The diameter of the minimum circle of confusion thereby produced was upwards of 0·04 mm., nearly twice as wide as the normal slit and three times the theoretical diameter of the central diffraction disc. As a result not only is a large percentage of the star light intercepted by the slit jaws and the exposure consequently increased, but, what is in one sense much more serious, the aberration in the star image renders

it almost impossible to obtain uniform illumination of the collimator and camera lenses by the star light, and introduces a condition which may lead to a systematic displacement of the lines and a consequent error in the resulting velocity.

It was furthermore shown, by a comparison of the exposure times required here with those of other installations, that a similar defect probably existed in other spectrographic equipments and that an improvement in the Ottawa corrector would point the way to a similar improvement elsewhere.

The matter was deemed of sufficient consequence to justify an energetic attempt at the improvement of existing conditions, and, with your hearty co-operation, a new correcting lens was ordered from the J. A. Brashear Co. The results of the investigation of the original corrector had previously been communicated to the Brashear Co. and to Prof. Hastings, who had designed it, and they were urged to do the best they possibly could.

Considerable delay ensued before Prof. Hastings completed the computations of the new corrector, partly on account of other duties and partly on account of the care and thought expended to secure the most efficient form. As the difficulty with the original corrector had been ascribed as partly due to its small aperture, about 2·25 inches, the new corrector was enlarged to 4 inches free aperture, effective aperture 3·8 inches, and consequently its position, as the ratio of focal length to aperture of the telescope is 15 to 1, was 15 × 3·8 or 57 inches within the focus. The lens could not be tested during the figuring in the same way as an ordinary lens on account of its requiring to have a stipulated amount of positive aberration to overcome the negative aberration due to the chromatic difference; moreover, it acts almost like a plate and cannot form any image by itself. Owing to the difficulties and delays involved, the objective could not be sent to the opticians to enable the combined system to be made free from aberration. Consequently Prof. Hastings devised an ingenious method of obtaining the correct figure without using the ordinary methods of testing. The radii of the surfaces and the thicknesses of the two elements were so computed that, assuming truly spherical surfaces, the system of objective and corrector would be free from aberration at the desired region. Such surfaces can be accurately figured and tested, the concave surfaces at the centre of curvature by the Foucault or knife edge test, and the convex, which are of the same radius as one of the concave, by interference fringes.

Although the Brashear Co. did not receive the data from Prof. Hastings until July, they completed the new lens in a very short time, and it was promptly sent to us, being received in the early part of August. Owing to its larger aperture and greater distance from the focus, the old form of mounting would not answer. This consisted of about 20 inches of 3-inch tube, the cell of the correcting lens being screwed in one end and the other sliding in a flanged casting which screwed in the end plate of the telescope. Such a tube for the new corrector would need to be about four feet long, and flexure would be certain to throw it out of collimation. A guide ring, into which this tube would easily slide, was consequently placed about three feet up the telescope tube, held in place there by three radial bolts passing through the latter and screwing into the ring, whose position was adjusted and maintained central by nuts on the outside of the telescope tube. This central position was determined and the exact collimation of the spectrograph tested in the following way: The correcting lens was removed from its cell and replaced by a thin circular metal plate with a hole about ⅛ inch in diameter exactly central. A similar plate was placed at each end of the central tube of the spectrograph in which the collimator tube slides, the latter being removed for the purpose. Finally the main objective was removed and a board with a minute central hole through which fine piano wire was threaded was inserted in its place. When the telescope was pointed to the zenith, the wire threaded through these metal plates, and a heavy weight hung on the lower end, it was very easy to obtain the correcting lens cell and the optical axis of the spectrograph exactly collimated. The eye can readily judge whether the wire is

exactly central in holes of small diameter, those in the ends of the central tube being observed direct, while that in the end of the corrector mounting was observed by the bent guiding telescope. The central position was obtained by adjusting the guiding ring before mentioned and, when once obtained, the adjustment would be permanent. Furthermore the spectrograph itself was exactly collimated by filing one or more of the attaching lugs, so that, when the telescope is pointed at the zenith, the collimation is correct. When pointed at any other hour angle or declination, however, flexure of the telescope tube will slightly affect this adjustment. This cannot be avoided, and, as the flexure and consequent departure from collimation will depend on the hour angle and zenith distance, it is evident that adjustment for the zenith is the best mean value obtainable.

Having thus ensured that all conditions of mounting were as perfect as possible, I was naturally anxious to determine whether the new lens would fulfil the purpose for which it had been designed, and to this end it was necessary to repeat the tests previously made with the original corrector. I had become so familiarized with the illumination pattern on the collimator lens, as observed through the camera of the spectrograph, that it was felt, as soon as the telescope was pointed at a bright star, it could be at once decided whether the corrector gave a good image. The appearance was, however, disappointing for, although there was a slight improvement over the old lens, the illumination pattern was still very far from being as uniform as it should be, if the image were free from aberration.

As soon as possible the actual form of the image was determined, exactly as in the former paper, by Hartmann's method of extra-focal measurements. The mean of a number of such measurements is used and the zonal differences of focus are plotted in curve B, Fig. 2. For comparison the curve for the original

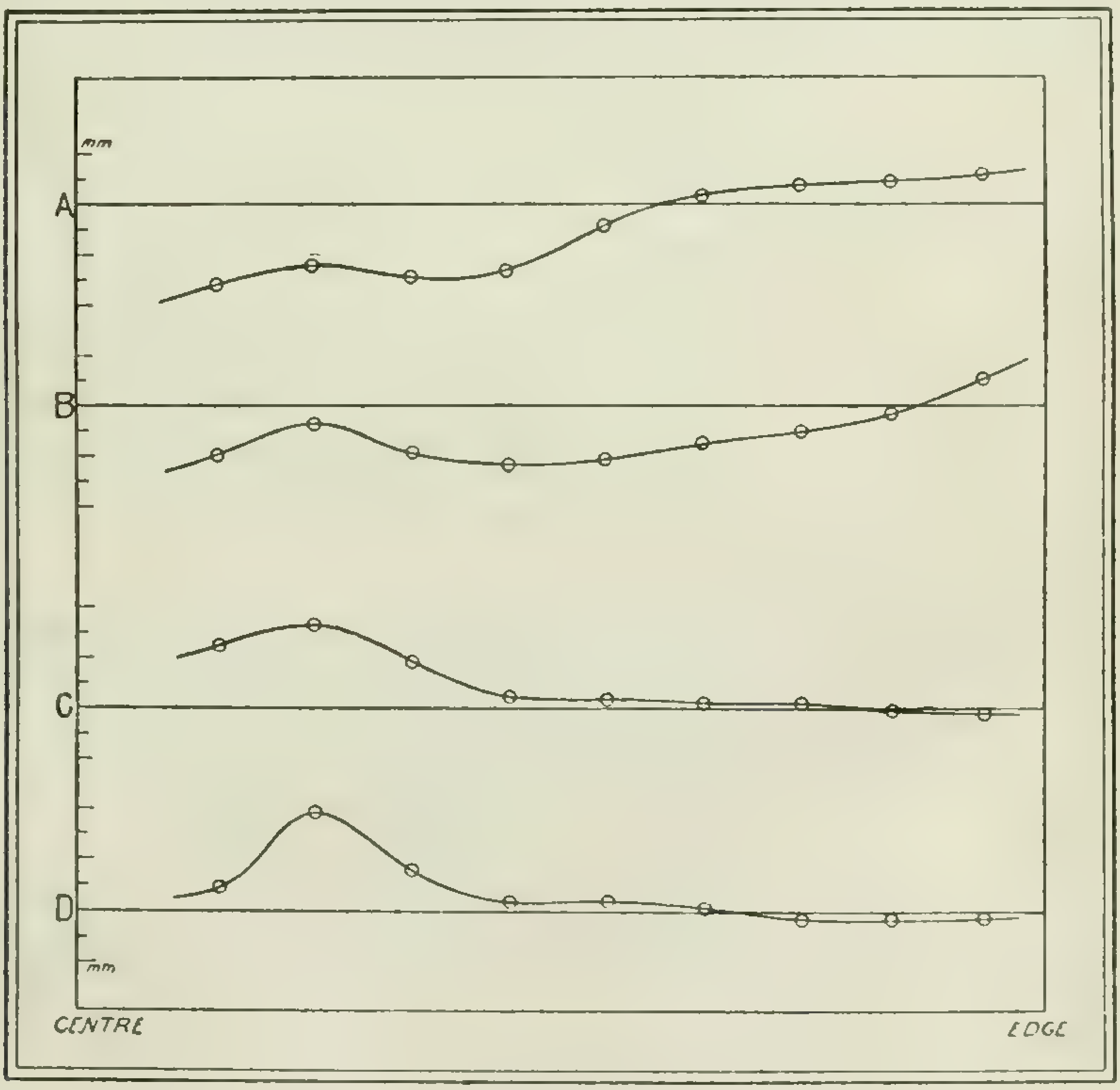


FIG. 2—Zonal Differences of Focus.

corrector is reproduced in A. while D gives the differences of focus for the objective used visually.

It is evident from a comparison of the curves for the two correcting lenses, that the same trouble exists in the new lens as in the old, for, although there is some slight improvement, it does not yet compensate for the chromatic differences. Its curve, however, is more regular and nearly similar to the visual curve, and this, taken in conjunction with its larger aperture, should allow it to be more readily corrected by refiguring. In actual use, however, it is doubtful whether much improvement would be noticed on account of the greater inclination of the curve at the outer zones, which have the greatest effect in determining the character of the image. This disappointing failure to fulfil the computed results must doubtless be ascribed to the small unavoidable departures of the actual from the computed radii of curvature, thickness, &c., of the elements, which may easily account for the small remaining aberration. Apparently the only chance of improvement is to be sought in refiguring the surfaces to introduce the required amount of positive aberration. A reference to Fig. 2 curve B, shows that if the focus for the edge with respect to the centre be shortened by 1·5 mm. and if the shortening be gradually decreased until a median zone is reached, the image will be as good as desired.

As soon as the actual form of image given by the combination was determined, I communicated the data to the J. A. Brashear Co., and asked them the best means of obtaining a better figure. Three methods could have been followed. 1st. To send objective and corrector to Allegheny; 2nd. To have an optician come to Ottawa and do the necessary figuring and testing here; 3rd. To send or take the corrector to Allegheny and have the edge focus shortened by the required amount. The first method is practically barred, on account of the difficulties and delays involved and the loss of the use of the objective for probably a month. Of the other two, Mr. McDowell informed me that he was certain he could readily introduce the required positive aberration, and thought the last method preferable. Therefore, by your kindness I took the corrector to Allegheny, being prepared to make there the Hartmann tests in addition to the visual tests of Mr. McDowell.

On reaching Allegheny on Wednesday, September 18, and talking over with Dr. Brashear and Mr. McDowell the best methods of testing the figure, it was at first proposed to use a spherical mirror with the source of light at the centre of curvature, to insert the corrector 57 inches, the computed distance, within the focus and test the aberration before and after refiguring. By this means, as will be readily seen, the light will pass twice through the lens, once in each direction, thus complicating matters. Moreover, no test could be made by the Hartmann method, as the plate would intercept the light. Further discussion of the matter resulted in an alternative method in which the lens would be tested under nearly the same conditions as those under which it was used.

A beam of parallel light was produced by placing an artificial star at the focus of a 6-inch objective. Centrally in this beam a 4-inch objective of 60 inches focus was placed, and 3 inches behind this, and consequently 57 inches from the focus, the corrector was inserted, thus intercepting a pencil of the same diameter and convergency and at the same distance from the focus as when used in its computed position at Ottawa. The image could then be examined at the focus either visually by the Foucault method or photographically by the Hartmann method.

A preliminary Foucault or knife-edge test with red monochromatic light, which was used in this test on account of the difficulty of obtaining monochromatic blue, showed that the edge focus of the system of 4-inch objective and corrector was about 0·7 mm. shorter than the focus at the centre. This is an indication, since presumably the 4-inch objective is free from aberration for light of this wave length, that positive aberration to the extent of about 0·7 mm. was present in the corrector. The chromatic difference of the 15-inch objective is about 2 mm., and hence this test

showed that the corrector required an increased amount, previously estimated at about 1·5 mm., of positive aberration. A Hartmann test, using photographic light, showed the difference between centre and edge to be about 0·2 mm. The difference between this and the visual test of 0·7 mm. is almost exactly that due to the chromatic difference of the 4-inch objective. Thus all the tests were in accord with one another and gave increased confidence in the reliability of each.

After a few minutes figuring of the outer concave surface, a visual test showed a difference between centre and edge of about 4 mm., which was considerably too great. However, Mr. McDowell's skill in figuring enabled him at the second trial to get the surface so nearly right that repeated tests by different observers showed the difference from the required amount 2·2 mm., to be indeterminable. A confirmatory Hartmann test showed the positive aberration present to be about 1·8 mm., 1·6 mm. greater than before figuring.

The corrector was therefore considered completed and the short time required to polish, less than five minutes if the time spent in carrying it too far and bringing it back be deducted, is an indication that its failure to fulfil its computed purpose is probably due, as was stated above, to slight deviations of the actual from the computed figures unavoidable in practice.

In this connection I wish to express my appreciation of the generous manner in which the John A. Brashear Co. have treated us in this as well as in all other matters, and my admiration of their skill in producing perfect optical surfaces.

Immediately upon my return from Allegheny, a Hartmann test was made of the performance of the refigured corrector. Using lantern plates and Capella as in the previous paper, the mean of a number of measures is plotted graphically in curve C, Fig. 2. A comparison of curves C and D shows that the deviations from the mean focus are less with objective and corrector than with objective alone, although this advantage is probably counterbalanced by the greater astigmatism of the former system in the other zone. If Hartmann's criterion 'T' is computed for objective and corrector, as was done in the previous paper for objective alone with a value of 0·141, it is found to be 0·118, showing the system to be almost perfect so far as zonal aberration is concerned. The small deviation near the centre is of no practical importance owing to the relatively small area and to the narrow convergency of the pencils, and probably arises, as the visual curve shows, in the objective itself.

Determinations of the colour curve of objective and corrector for a median zone were made by Hartmann's method and the results are given in Table II and are plotted in Fig. 3.

TABLE II.

COLOUR CURVES NEW CORRECTOR.

Wave Length.	Normal Position.	76 mm below Normal Position.	48 mm above Normal Position.	Old Corrector.
3,900		79·87	74·42	50·85
3,933	75·29	79·36	73·82	49·97
3,970	74·80	78·49	73·05	49·34
4,035	73·91	76·94	72·48	48·29
4,102	73·06	75·95	71·87	47·32
4,175	72·65	75·78	71·61	46·42
4,250	72·24	74·55	71·40	46·11
4,342	72·26	74·26	71·65	45·62
4,415	72·38	74·04	72·04	45·47
4,501	72·71	73·92	72·52	45·36
4,590	73·15	74·24	73·26	45·69
4,680	73·68	74·68	74·05	46·04
4,765	74·55	75·23	74·77	46·50
4,861	75·22	76·02	75·85	46·99
5,050	76·35	77·56	77·93	48·85

Curve A is for the corrector in its computed position 57 inches above the focus, curve B 59 inches, and curve C 54 inches above the focus, while curve D is for the old corrector. These curves show that the point of minimum focus can be shifted to the red by lowering, and to the violet by raising the correcting lens, and this

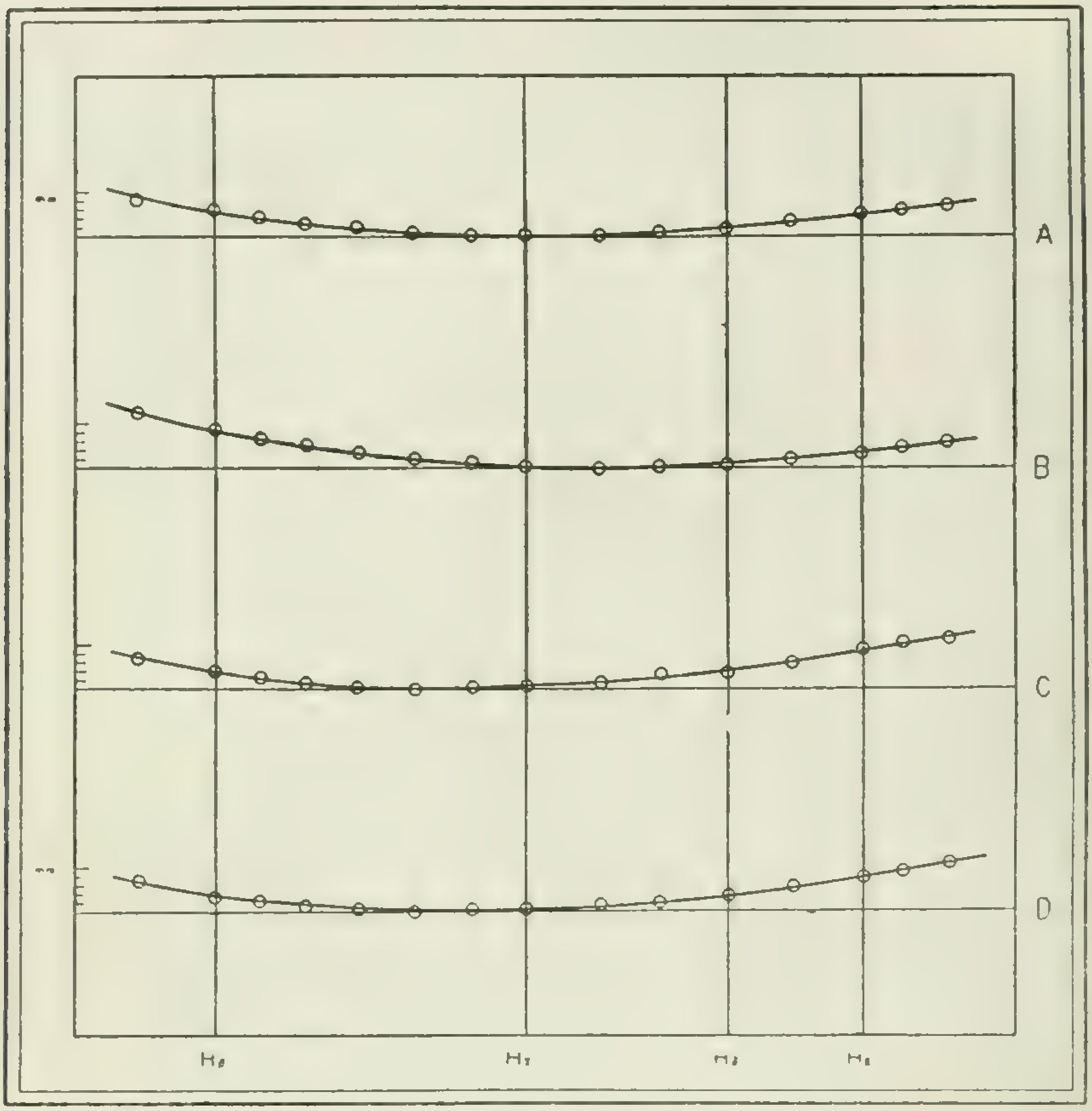


FIG. 3—Color Curves.

knowledge may be of value if, for any cause, the portion of spectrum under observation were changed. As is to be expected, the colour curves for new and old corrector do not differ appreciably in form.

It may be of interest to give some figures showing the exposures required to obtain measurable spectra with the new correcting lens. In the three prism plates, which have been confined to solar type stars, the region measured lies between λ 4340 and λ 4580 and the exposure was sufficient to give good intensity over the range. In the single prism plates, the region measured lies between H_β and K, and the exposure was sufficient to allow K to be accurately measured and to shorten up the diffuse H lines, which is, I should estimate, more than twice that required in a solar type star of the same magnitude, around λ 4500. In single prism work, in order to render the spectrum more uniform in intensity, the slit is placed about 2 mm. below the minimum focus, so that star light of wave lengths about λ4000 and λ4800 is in focus on the slit.

Three Prism Spectrograph.

Linear Dispersion 10·0 tenth-metres per mm. at $H\gamma$

Star.	Photc. Madge. Draper Cat.	Slit Width.	Exposure.
η Piscium..	5·0	·038 mm.	70 mins.
ϵ Cygni..	3·85	·030 "	40 "

Single Prism Spectrograph.

Linear Dispersion 30 tenth-metres per mm. at $H\gamma$

Star.	Photc. Madge.	Slit Width.	Exposure.
ι Orionis..	3·4	·030 mm.	10 mins.
o Andromedæ..	3·9	·030 "	25 "
ψ Orionis..	4·6	·035 "	40 "

As these figures show, the exposure times required, considering the size of the telescope, are short and compare favourably with those of any installation, although enough data have not yet been secured with the three prism spectrograph to make accurate comparisons possible. If the magnitude of η Piscium, which is assigned as 5·02 in the Draper Catalogue, is reliable then a star of the 5th photographic magnitude could be photographed in two hours with a slit ·025 mm. wide and linear dispersion of 10 tenth-metres per millimetre, a very efficient performance for a 15-inch objective especially in the generally unfavourable conditions at Ottawa. Again, if the exposures given with the single prism spectrograph be reduced by 50 per cent or more, as would occur were the slit set at the focus for λ4400, and the spectrum made accurately measurable around this region, they would indicate similarly a very efficient condensing system. So far as the data at hand go, they indicate a decrease in the required exposure time with the new corrector of upwards of 30 per cent, and if Table V* of Appendix B of last year's report be reconstructed under these new conditions it would show the relative efficiency of the Ottawa installation to be equal if not superior to that of any other. The successful issue of the attempt to improve the photographic image given by the Ottawa objective and corrector is of value, not only on account of the increase in range and efficiency of the equipment, but also because of the greater freedom from chance of systematic displacement of the lines due to the more uniform illumination of the collimator ensured by an image free from aberration. It is also of value as showing the possibility of obtaining a practically perfect corrector without sending the objective to the optician.

Another advantage, so far as this investigation is concerned, is the assurance of having a star image free from aberration as a starting point for a trustworthy investigation into the actual effect of atmospheric disturbances on such an image. Some experiments were made, as recounted in the previous paper, on the effective diameter of the star image, but, owing to the aberrations present in the old corrector, the results obtained only gave the combined effect of aberration and atmospheric tremor. Since the former has been removed, a repetition of the experiments should give an accurate knowledge of the effect of the latter. Newall has already given†, principally from theoretical considerations, a very valuable discussion of the effect of such an enlarged image on the design of spectrographs, and it seemed to me that a description of some experiments bearing on the same point, with the conclusions reached, would also be of value. Newall considers the effective star image to be composed of a central 'core,' as he calls it, surrounded by a more diffuse 'tremor

*Since the Table referred to was published, Mr. V. M. Slipher has informed me that the exposure times assigned to the Lowell equipment were too large. They were taken from his paper on Standard Velocity Stars, but Mr. Slipher states that the early plates were not only overexposed but that the spectrum was made much wider than necessary. Under such conditions the Lowell equipment would make a much more favourable showing.

†M. N. LXV., p. 608.

disc' and calculates on such an assumption the quantity of light transmitted by slits of different widths for different diameters of core and tremor disc. I shall attempt to show how the percentage of light transmitted may be determined experimentally, and obtain from that and other experiments some conception of the form and dimensions of the star image.

If one examines the visual star image in a telescope by an eye-piece of moderate power, it cannot escape notice that the image is not stationary, that it is displaced in all directions from its mean position and moreover that the central diffraction disc is frequently expanded in a greater or less degree. The light in the bright rings surrounding the central disc together with these two phenomena due entirely to atmospheric effects may be assigned as the cause for the enlargement over theoretical dimensions of the star image on a negative. The effects are all summed up in the resultant image, very much increasing its diameter over that due to the central disc alone.

As a test of this hypothesis, stars of different magnitudes were photographed, a number of different exposures being given to each star. The diameter of the images varied from 0·050 mm. equivalent to 1″·8 for a faint star with short exposure to 0·130 mm. or 4″·7 for a bright star with medium exposure. A number of these images of moderate exposure had a central nucleus of about 2″ diameter, surrounded by an outlying penumbral portion some 3″ or 4″ in diameter. The diameter and intensity of this penumbra increased with increase of exposure, until in the longer exposures on bright stars its intensity became equal to the nucleus, resulting in the largely increased diameter noticed. Photographs of Capella on lantern plates with exposures from 10 to 40 secs. gave images of diameters from 0·13 to 0·17 mm., or from 4″·5 to 6″, and these images differed from those of shorter exposure on fainter stars by being more sharply defined at the margins and of uniform intensity throughout. The minimum effective diameter of star image seems, therefore, to be in the neighbourhood of 2″, though this will evidently vary with the conditions of seeing. The diameter remains nearly the same for a considerable range of exposure, and then begins to increase until it reaches about 6″, although part of this may be due to the spreading of the light in the film or to halation.

If the star be allowed to trail on the plate, the width of trail will give us a measure of the effective diameter of the image, and its appearance some idea of its character. The trails in every case, even in good seeing, were broken and jagged, showing the dancing of the image previously referred to. The enlargement or blurring is shown by the widths of the trails, which, for a third magnitude star on a lantern plate, ranged, even in the narrowest short parts, from 0·035 to 0·048 mm., or from 1″·25 to 1″·7 upwards of twice the diameter of the central disc. For Capella the widths were from 0·050 to 0·065 mm., 1″·8 to 2″·3. If the microscope wires were set tangent to a longer strip of the trail, the above figures were increased about 30 per cent. For the old corrector the widths ranged from 0·070 to 0·110 mm., practically twice as great as with the refigured lens.

The widths of star spectra made under different conditions of exposure and focus were also measured and ranged from 0·048 to 0·110 mm. In order to prevent any widening due to drift in right ascension, the spectrograph was turned in position until the slit was parallel to an hour circle. As the focal lengths of collimator and camera are equal, the widths obtained give a measure of the effective diameter of the star image. The star used was Vega, which was chosen for two reasons, the shortness of exposure required ensuring freedom from possibility of drift, and the type of spectrum rendering it certain that the full width was obtained. Similar experiments with solar type stars showed that the discontinuous nature of the spectrum rendered it apparently much narrower.

It will be of interest here to give a table showing the increase of width with increase of exposure.

TABLE III.

Exposure. secs.	Width. mm.	Diameter in Secs.
5	0·048	1·7
10	0·049	1·7
15	0·060	2·2
20	0·075	2·7
30	0·086	3·1
45	0·095	3·5
90	0·110	4·0

The above figures show how the outlying parts of the 'tremor disc,' which has a 'core' of about 1″·7 diameter, increase the width of the spectrum when the exposure is sufficiently prolonged to allow them to act on the plate.

With the old corrector the widths ranged from 0·085 to 0·115 mm., considerably wider than those given above.

The above experiments indicate that Newall's hypothesis in regard to the character and dimensions of the star image is in close agreement with the observed facts. The dimensions seem to point to a tremor disc about 5″ diameter, with a core 2″. If the proportions of the light, transmitted by slits of different widths on which such an image is incident, be computed, and if we obtain, exactly as was done before, the proportional exposures required to obtain spectra of equal intensity over the same range of slit-width, a comparison of the two should show whether the assumption made is justified. In any case the experiment will show the actual loss at the slit, and this will be of value as indicating the direction in which improvement may be reached.

Three stars were used in this test, Vega, Capella and γ Cygni, and the spectra were made of the usual width, the greatest possible care being taken to ensure uniform exposure over that width in order that they could be accurately compared. The exposures were so regulated as to obtain as nearly as possible equal intensity. Thus, neglecting plate factors which, within the limits of exposure time and intensity used, will not appreciably affect the result, a direct estimate of the percentage of light transmitted is obtained. The mean of a number of tests gives figures according to the following table; the seeing during these tests being slightly above the average.

TABLE IV.

SLIT TRANSMISSION.

Slit Width.			Comparative times for equal of spectrum intensity.		
Divs.	Mm.	Secs.	Observed.	Eliminating diffraction.	Computed $\tau=5''\gamma=2''$
1	·025	0·91	100	100	100
2	·050	1·82	40	50	54
3	·075	2·73	27	35	39
4	·100	3·64	25	32	34
5	·125	4·55	23	29	31
6	150	5·45	23	29	31
8	200	7·27	23	29	31

In the above table the fourth column gives the observed times for equal intensities of spectrum, while the fifth is the same with a correction for diffractional losses in the collimator with the narrower slit widths. The sixth column is computed on the basis of Newall's hypothesis for a tremor disc 5″ diameter with a core of 2″. The computed percentages are slightly higher than the observed, indicating that the actual image is probably somewhat larger than the dimensions chosen for the computed one. It must be remembered, however, that these figures are approximate only, the nature of the test not permitting determinations closer than 5 per cent. Moreover, a change in the steadiness of the air would change the observed figures very considerably, the effect of poorer seeing being to increase the diameter of the tremor disc and core, and consequently diminish the silt transmission.

All the experiments on the diameter of images, widths of trails and spectra, and loss of light at the slit, indicate a form of star image which is of about the same dimensions and character as that supposed by Newall, and we may, with confidence, consider that the actual effective image of a star given on the slit plate is very much larger than has generally been supposed. Moreover, as the zonal tests have shown that the condensing system is free from aberration and the image almost perfect, the enlargement must be due to atmospheric disturbance of the wave fronts and can not be overcome by any optical system. As a result, with a slit of normal width ·025 mm., only 30 per cent or less of the light collected by a 15-inch objective can be transmitted. This difficulty is much more serious with objectives of longer focus, as the image is probably enlarged proportionally. Indeed, Wright's tests* show that the Mills spectrograph only makes use of about 12 per cent of the light collected by the 36-inch telescope, and this in the unequalled atmospheric conditions of Mt. Hamilton. Part of the advantage of increase of aperture is thus lost by the consequent increase in the effective diameter of the image. The only means of diminishing this loss lies in using wider slits in our spectrographs. For example, a slit ·05 mm. wide with the 15-inch objective would transmit about 55 per cent of the incident light, while a slit ·075 mm. wide nearly 80 per cent. Unfortunately wider slits mean diminished purity and loss of accuracy, although, as is shown in the investigation below, the probable error of radial velocity determinations in early type stars by no means increases proportionately with the increase of slit width. These results also indicate the importance of using as large a collimator aperture as is consistent with homogeneous prisms, the consequent longer focus allowing increased slit width with equal purity. The question of spectrograph design, however, has been shortly discussed under the sub-heading 'The Spectrograph,' and nothing further need be added here.

MEASUREMENT AND REDUCTION OF STELLAR SPECTRA.

Measuring Machines.

All the spectra made here, with the exception of a few for which the Zeiss Scale Comparator was employed, have been measured on the Toepfer Measuring Microscope Model II. Continued use of this machine has confirmed the good opinion previously formed of its accuracy and convenience. Besides obtaining an extra objective of medium power over a year ago, two oculars of longer focus than the one originally supplied have recently been obtained and one of these is now constantly in use. The cross wires in the field are thereby made apparently narrower and, when a higher power objective is used (the power of the whole microscope not necessarily being changed) they do not cover up so much of the finer star or comparison lines so that more accurate settings can be made. A second improvement, which will be applied as soon as Mr. Mackey has time to make it, is an additional slide for adjusting and setting the negatives without running the main carriage backwards and forwards by

*Publications of Lick Observatory, Vol. IX., Part 3.

means of the screw. This will be more convenient, will allow any line of the negative to be set at any desired micrometer reading, and will prevent unnecessary wear of the screw.

Special stands with covers for the instruments when not in use are being made both for the Toepfer machine and for the Hartmann-Zeiss Spectro-Comparator which has just arrived. An ordinary table is somewhat too high, and the stands are being made of suitable height and of such dimensions as will conveniently hold the machine and a pad for entering the readings. Besides being more convenient in use and avoiding replacing the machine in the box when the measurement is completed, considerable space will be saved.

The Spectro-Comparator, in which the radial velocities are determined by directly comparing the displacement of the star lines with the corresponding lines of a standard or fundamental spectrum and in which consequently no knowledge of wave length is required, seems a very workmanlike and accurate instrument, but has not yet been placed in regular use. Consequently, a description of the instrument and of the method of measurement may preferably be deferred to the next report. Undoubtedly this machine will be of special value in the measurements of spectra rich in lines (of the solar and allied types) whether taken with high or low dispersion, and for these a marked saving in time as well as increase in accuracy will be obtained by its use. For spectra with few lines, especially where these are diffuse, the method usually followed of making linear measurements of the star and comparison lines and reducing to wave lengths by an interpolation formula, or obtaining the displacement directly by the use of suitable tables as is now done here will be found preferable. Consequently, each machine will have its own field for which it is best adapted, and the measurement may be suitably divided between them.

Method of Measurement.

In measuring a spectrogram by the Toepfer microscope, the method first adopted has since been followed almost without change, and may be again shortly described. The carriage having been moved to the middle of its range, micrometer reading 50·0, the negative is fastened on the plate glass top by spring clips with the red end of the spectrum to the left and the Fe line λ 4415, which is at minimum deviation, centrally under the wire. By moving the carriage back and forward, the spectrum may be oriented by the tangent screw provided until it is parallel to the direction of motion. The carriage is then moved to the right until the part of the spectrum where measurement is to begin is reached. This is, in the single prism plates, usually the comparison line λ 4864. The micrometer readings therefore diminish with the wave lengths, thus avoiding negative signs in the interpolation formula. On each star line 4 settings are made, 2 with forward, 2 with backward rotation of the screw. On each comparison line similarly 4 settings are made, one forward and one backward on each of the portions above and below the star spectrum. When this half of the measurement is completed, the plate is reversed so that the red end is to the right and the process repeated. Each measure in the second position is subtracted from a suitable number, (generally about the sum of the two measures of a line) and the final micrometer reading determined from the mean of the eight settings. This reversal of the plate is always necessary to overcome the difference in the settings on the dark comparison and light star lines in the two positions. With myself this difference, especially in the case of diffuse star lines is considerable, while with Mr. Harper the differences are always small. Comparisons show, however, that, after reversal, the final values obtained are practically the same for both observers.

The probable error of a single setting on a good comparison line will certainly not exceed ·002 revolution or ·001 mm., and on a good star line will be somewhat less than this, while the probable error of the mean in each position of the plate will only be half the above. The probable errors, as deduced from the final velocity values for

the star lines, will be considerably greater than above, the ratio depending on the character of the spectrum and on the dispersion of the spectrograph as affecting the resolution of blends whose effective wave length is uncertain.

Reduction of Stellar Spectra.

So far as the spectra produced by the single prism spectrograph are concerned, the method of reduction described in last year's report based upon that devised by Hartmann* has been followed exclusively. It has been found very satisfactory, both the time and labour required being reduced to a minimum. There has since appeared [1] a method by Dr. Schlesinger on a somewhat similar plan, but without any apparent advantage over the former. Indeed, after the tables of micrometer readings for star and comparison lines have once been computed the reduction by the former method is slightly simpler and equally accurate.

The Hartmann method has since been applied to plates made with the three prism spectrograph using the Hartmann-Zeiss 'Chromat' camera objective of 528 mm. focus giving a linear dispersion at $H\gamma$ of about 10 tenth-metres to the mm.

Measures were made as before of a number of comparison (Fe, V spark) spectra at 3 different temperatures (+15·9° +21·1° +26·8°C). From standard lines chosen at different places in these spectra, using the complete Hartmann formula $s_0 - s = \dfrac{c}{(\lambda - \lambda_0)^{\alpha}}$. Mr. F. W. O. Werry, who has ably performed all the computation required in this work, determined sets of constants for values of α between 0·5 and 1·0 by steps of 0·1. Using these constants the residuals obtained by subtracting the observed from the computed micrometer readings of the lines measured were compared. It was found that the residuals were the smallest when $\alpha = 0{\cdot}5$, and that they were on the whole the most satisfactory when the three chosen standards were near the middle of the range of spectrum measured. Thus the residuals for the standards λ4494·755, 4315·255, 4199·256 were more satisfactory than when the lines λ4864·943, 4395·382, 4099·920 were used as standards. Consequently, constants for the three temperatures were computed, taking $\alpha = 0{\cdot}5$ and using the lines λ4494, 4315 and 4199 as standards. These are tabulated below with the corresponding micrometer readings.

TABLE OF CONSTANTS.

Temp. C	4494·755 s_1	4315·255 s_2	4199·256 s_3	s_0	log c	λ_0
15·9	163·4019	130·9354	104·8351	537·9128	4·1078875	3322·975
21·1	163·3790	130·8597	104·7295	539·2839	4·1099020	3320·806
26·8	163·3965	130·8390	104·6593	538·5569	4·1084358	3324·076

As in the similar work with the single prism, there is a general progression which is more clearly shown by some measurements later made at lower temperatures. These indicate that in the plate at 21·1° temperature there is some cause, possibly inaccurate camera focus (a change of 0·1 mm. would easily account for the difference), rendering its values discrepant, and it was therefore not considered in determining

* A. N. No. 3703.

[1] Publications Allegheny Observatory, Vol. 1, No. 2.

the arbitrary values of the s's and the ratios between them chosen for the six temperatures $-20°$, $-10°$, $0°$, $+10°$, $+20°$, $+30°$, for which tables were computed. The differences of the s's and the log $\frac{s_1 - s_2}{s_1 - s_3}$ are given below for four temperatures.

Temp. C	$s_1 - s_2$	$s_2 - s_3$	$s_1 - s_3$	Log $\frac{s_1 - s_2}{s_1 - s_3}$
9·9	32·4025	26·0247	58 4272	9·74396
15·9	32 4665	26·1003	58·5668	9·74378
21·1	32·5193	26·1302	58·6495	9·74387
26·8	32·5575	26·1797	58·7372	9·74373

From experience with the working of the single prism tables, where the change of the ratio of $s_1 - s_2$ to $s_1 - s_3$ was made a little too great, the increment to be added to the logarithm of this ratio for each 10° change of temperature was made 5 in the last place and the logarithm was taken as 9·74395 for 0°C. The value of $s_1 - s_3$, for 10° was chosen as 58·4500 and its change was made ·1800 for every 10°. In order to bring the line λ 4415·293, the line at minimum deviation, as close as possible to micrometer reading 150·0000 the values of s_1 were chosen as given below and the final tables show, by the close agreement of the computed micrometer reading for the line λ 4415·293 with 150, that these values were nearly correct.

ARBITRARY VALUES CHOSEN.

Temp. C.	$s_1 - s_3$	log $\frac{s_1 - s_2}{s_1 - s_3}$	$s_1 - s_2$	$s_2 - s_3$	s_1
−20	57·9100	9·74405	32·1221	25·7879	163·2480
−10	58·0900	9·74400	32·2182	25·8718	163·2860
0	58·2700	9·74395	32.3143	25·9557	163·3240
+10	58·4500	9·74390	32·4104	26·0396	163·3620
+20	58·6300	9 74385	32·5065	26·1235	163·4000
+30	58·8100	9·74380	32·6025	26·2075	163·4380

From the above table the values of s_2 and s_3 were readily obtained by subtraction, and the values of the constants as computed by Mr. Werry are given in the next table.

CONSTANTS.

Temp. C.	4494·755	4315·255	4194·256.			
	s_1	s_2	s_3	s_0	Log c.	λ_0
−20	163·2480	131·1259	105·3380	536·0670	4·1070976	3316·609
−10	163·2860	131·0678	105·1960	536·7883	4·1076707	3317·813
0	163·3240	131·0097	105·0540	537·5152	4·1082533	3318·993
+10	163 3620	130·9516	104·9120	538·2138	4·1087884	3320 242
+20	163·4000	130·8935	104·7700	538·9429	4·1093742	3321·400
+30	163·4380	130·8355	104·6280	539·6538	4·1099295	3322·600

Using these constants the micrometer readings corresponding to all the wave lengths used, both star and comparison, were computed for each temperature and

tables formed as in single prism work. The velocity values of one revolution of the micrometer screw are also required and these are readily obtained by differentiating the interpolation formula and applying Doppler's principle.

$$s_0 - s = \frac{c}{(\lambda - \lambda_0)^{0 \cdot 5}}$$

$$ds = \tfrac{1}{2} \cdot \frac{c\,d\lambda}{(\lambda - \lambda_0)^{1 \cdot 5}}$$

and $$v = 299860 \cdot \frac{d\lambda}{\lambda}$$

$$v = \frac{299860 \cdot 2(\lambda - \lambda_0)^{1 \cdot 5} \cdot ds}{\lambda \qquad c}$$

The tables formed as described are used in reducing the three prism plates in exactly the same way as described in the last report for the single prism plates and effect an equal saving of time and labour with the former.

The corrections for curvature of the spectral lines and for the diurnal and annual motions of the earth are applied in the usual way and no description of them is necessary here.

EFFECT OF SLIT WIDTH.

The experiments on the effective dimensions of the star image, given under 'New Correcting Lens' above, showed the importance of using as wide a slit as is consistent with accuracy in velocity determinations. Every spectroscopist has observed how wide and diffuse the lines of both emission and sharp absorption spectra become when the slit is made say ·075 mm. wide, and indeed the gradual increase in diffuseness is noticeable as the slit is widened from say ·02 mm. This increase is not so marked when the focal length of the collimator is considerably greater than that of the camera, as the width of the image of the slit is evidently reduced in proportion to the ratio of camera to collimator. When camera and collimator are of the same focal length, the image of the slit is of the same width as the slit, whereas if, for example, the camera is only half the focal length of the collimator the image of the slit is only half as wide as the slit itself. Consequently, in the latter case, the diffuseness of the lines is not so obtrusive.

It becomes a question of much interest to what extent the accuracy of velocity determinations is diminished by an increase in slit width. This can only be determined by actual experiment, by making exposures on suitable stars at the different slit widths and measuring and reducing the spectra. In order to obtain results of value, there must be a sufficient number of measurements at each slit width to prevent accidental discrepancies of some lines or plates from appreciably affecting the final result or influencing the conclusions drawn from these results. As the labour involved in measuring and reducing spectra is considerable this number at each slit width was limited to six, although it was felt that double the number would be preferable.

Evidently the loss of accuracy occurring as the slit is widened may be due to two causes: 1. The diffuseness of the lines of a spectrum will diminish the accuracy of setting on the individual lines, will increase the accidental errors and the residuals from the separate lines, and consequently also the probable error of the mean. 2. A systematic displacement of the star lines with respect to the comparison lines, resulting in an error in the velocity, may occur when the slit becomes wider than the diameter of the image owing to its unsymmetrical position with respect to the slit jaws.

These two sources of error are in one sense entirely independent of each other. The former may easily be evaluated independently of the latter by treating the residuals from a sufficient number of measurements of star lines on a number of

plates, these residuals being obtained for each plate from the mean velocity for that plate. The effect of the latter can only be obtained from such a number of complete velocity determinations that the systematic displacements may be considered accidental.

In considering errors from the first cause, it is necessary to limit the conditions so that only errors of setting will occur, and no error due to lack of resolution will be a factor. This is, of course, easy enough to do by limiting the stars observed to those of the early types, where all the lines are single and no question of the wave lengths of blends will occur. This presupposes the method of measurement to be that usually followed, linear measures of the positions of star and comparison lines along the spectrum and reduction to wave lengths by an interpolation formula. However, if two similar spectra of the same resolution even if rich in lines and blends are compared by the spectro-comparator, questions of wave length are eliminated and only, as before, the accidental errors of setting of the groups of lines remain. It was felt, however, that the comparison would be more direct, that only errors of setting due to increase in diffuseness and width would occur if the experiments were limited to stars of one type containing only a limited number of single lines so separated that, in no case, could adjacent lines merge into one another as the slit widened. Furthermore, in early type stars the lines are frequently diffuse and difficult to set upon, rendering the velocity determination uncertain to a considerably greater extent than with second type stars. Where very accurate determinations are not possible in any case, a slightly increased probable error may be permitted more readily than where, with ordinary observing conditions, reliable and accurate velocities can be obtained. To further shorten the labour involved the experiments were confined to one star and β Orionis was chosen as being on the whole the most suitable. The character of its spectrum, containing a number of single lines only moderately sharp, is such as to make the test as general as possible, combining, so far as may be, both sharp and diffuse lines. Its brightness renders only short exposures necessary, although, as will be seen later, this may not be advantageous so far as systematic displacements are concerned.

As mentioned above, six spectra were obtained and measured for each slit width tested, at three different dispersions of the new spectrograph, making in all 66 measures. Of these measures 18 were made by Mr. Harper, the balance by myself. As about 15 lines, star and comparison, were measured in each spectrum and eight settings were made on each line, this means nearly 8,000 settings of the micrometer screw.

The three dispersions used were as follows. Collimator focus in all cases 525 mm.

(*a*) Single prism spectrograph, Brashear single material camera objective, 525 mm. focus. Linear dispersion at $H\gamma$ 30·2 tenth-metres per millimetre.

(*b*) Three prism spectrograph, Hartmann-Zeiss 'Chromat' camera objective, 525 mm. focus. Linear dispersion at $H\gamma$ 10·2 tenth-metres per millimetre.

(*c*) Three prism spectrograph, Ross special 'Homocentric' camera objective, about 275 mm. focus. Linear dispersion at $H\gamma$ 18·2 tenth-metres per millimetre.

With dispersions *a* and *b* four different slit widths 0·025, 0·038, 0·051 and 0·076 mm. were tested, while with dispersion *c*, only three 0·025, 0·051 and 0·076 mm. The Ross lens was not free from curvature of field and aberration and moreover, as only a temporary mounting was used, no temperature control could be applied. However, care was taken to make the exposures only when the temperature in the dome had reached a steady state, and, as the exposures were short, only five minutes for slit ·025 mm. and the comparison applied three times, the danger of systematic displacement due to changes of temperature is probably not great. Nevertheless this, along with possible discrepancies due to the aberration of the lens, causes somewhat less confidence to be placed in the results from dispersion *c* than from the others, and also led to the omission of plates for slit width 0·038 mm. from this set.

The desire to test the effect of increased slit width, when the ratio of collimator to camera focus was, as in this case, nearly two to one (in dispersions *a* and *b* the focal lengths of collimator and camera are equal) led to the use of this imperfect lens. The test will be repeated when a better one can be obtained.

The spectra given with dispersion *c* for wide slits 0·051 and 0·076 mm. certainly look to the eye much sharper than those obtained with the same slit with dispersions *a* and *b*, but the measures and comparison of the measures must be the final test, making allowance for the character of the short focus lens and the lack of temperature control.

The time of exposure required is much diminished as the slit is widened, indeed it is nearly inversely proportional to the width. The table below gives the mean times required to give equal intensity of spectrum.

	Exposure Times for Slit.			
Camera.	·025	·038	·051	·076 mm.
I L.	150″	90″	60″	45″
III S.	5′	...	3′	2′
III L.	14′	10′	8′	5′

This indicates how much saving of time would be effected could the slit be opened to a greater width than usually employed.

In the measurement of these 66 plates, the same lines both star and comparison were used in all plates of the same dispersion, although the star lines employed changed as the dispersion changed. This was due to a longer range of spectrum in the single prism spectrograph, and to differences in the best lines available with the different dispersions. The lines H_β, λ 4861·527, *Mg* λ 4481·400, *He* λ 4471·676 and H_γ λ 4340·634 were measured in all the spectra. In addition in the single prism plates the lines H_δ λ 4102·000, *He* λ 4026·352 and *Ca* 3933·825 were also measured. In the three prism plates with Ross Camera Objective (short focus) the lines *Si* λ 4131·047, *Si* λ 4128·211 and H_δ were measured. In some of the three prism plates with Zeiss 'Chromat' Camera Objective the same lines also including *He* λ 4388·100 were measured, while in others only the first four mentioned and *He* λ 4388·100.

All the measurements were reduced to velocities by Hartmann's method already described. As mentioned previously, tables have been constructed for dispersions (*a*) and (*b*) and these were used direct. For dispersion (*c*) constants of an interpolation formula were computed for one plate, and from these were calculated the micrometer readings corresponding to the wave lengths of the comparison and star lines used with, for the latter, the velocities in kilometres per second per revolution of the micrometer screw. Hence, as all the plates were taken at the same temperature, the others were readily reduced from the one first used. It has not seemed necessary to give the detailed measures of each plate in this case, but only to tabulate the velocities corresponding to each star line measured. The six plates for each slit width with each dispersion are grouped together making 11 sets of six plates each. Each line has been weighted according to its quality, and the weighted mean in every case is used. Below the separate measures is given the weighted mean of the plate for the different grouping of lines employed in obtaining residuals and probable errors. In this way one can much more readily compare the results from each line and each plate, also the results from sets of plates, than if the measure of each plate was tabulated by itself. The residuals from the lines can also be readily obtained and tabulated or treated in any desired way.

SESSIONAL PAPER No. 25a

SINGLE PRISM, CAMERA 525 MM. FOCUS.

Slit 0·025 mm.

Plate No.		1241a.		1241b.		1241c.		1242a.		1242b.		1242c.	
Wave-Length.		Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.
4861·527 H_β		1	34·54	1	12·48	1	30·04	1	40·20	1½	38·02	1	17·99
4481·400 *Mg.* ...		3	40·28	3	40·28	2	51·56	3	40·74	2½	43·76	3	33·61
4471·676 *He* ...		2	53·40	1	38·54	1	52·83	3	47·00	1½	50·75	2	54·55
4340·634 H_γ		3	35·17	3	38·41	3	35·49	2	36·53	3	41·34	2	27·97
4102·000 H_δ		1	34·37	1½	31·33	1½	36·10	1	31·33	2	26·99	1½	31·94
4026·352 *He*		1	49·72	1	44·76	1	40·69	1	50·86	1½	45·10	1	51·59
3933·825 *Ca*.......		2	39·40	2	45·09	1½	43.89	1	43·14	1½	59·40	1½	43·14
Wt'd. Mean.	All Lines ..	40·81		37·28		40·65		41·82		40·54		37·34	
	Three Lines ..	41·64		39·23		43·74		42·03		44·22		37·98	

Slit 0·038 mm.

Plate No.		1243a.		1243b.		1243c.		1244a.		1244b.		1244c.	
Wave-Length.		Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.
4861·527.........		½	26·56	1	14·07	1	30·48	1	26·99	1	8·86	1	33·28
4481·400		3	42·12	2	46·04	2	34·76	3	41·20	3	33·61	2	45·11
4471·676..........		2	36·94	2	46·43	2	48·26	2	43·11	2	36·25	2	49·97
4340·634........		3	38·93	3	35·80	3	45·19	3	44·25	3	35·07	3	41·02
4102·000		2	27·86	1½	28·21	2	30·03	2	32·55	2	23·08	2	35·84
4026·352..........		½	43·46	1	37·11	1	41·02	½	54·85	1	33·85	1	41·83
3933·825........		1	42·39	1½	36·40	2	40·30	1	51·01	1	42·24	1	39·77
W Mean.	All Lines ..	37·51		36·70		39·52		41·05		31·51		41·66	
	Three Lines ..	39·63		41·76		43·09		42·82		34·82		44·75	

SINGLE PRISM, CAMERA 525 mm. FOCUS.

Slit 0·051

Plate No.		1245a.		1245b.		1246c.		1249a.		1249b.		1249c.	
Wave-Length.		Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.
4861·527		1	32·22	½	4·93	1	24·96	1	20·61	½	46·00	1	22·86
4481·400		3	45·12	3	43·27	3	38·67	3	33·26	2	35·22	2	39·36
4471·676		2	46·54	2	38·53	2	41·97	2	33·96	2	39·11	2	51·57
4340·634		3	39·24	3	37·89	3	36·84	3	30·37	3	30·58	3	38·93
4102·000		2	31·50	2	20·57	2	26·07	2	31·33	2	26·56	2	23·35
4026·352		1	45·90	1	37·11	1	41·42	2	48·34	1	46·39	1	40·85
3933·825		.....	......	½	40·15	1	43·14	2	43·89	1	37·15	1	42·02
Wt'd. Mean.	All Lines...	40·61		35·11		36·32		35·10		34·79		37·52	
	Three Lines...	43·27		40·07		38·81		32·35		34·31		42·66	

Slit 0·076

Plate No.		1247a.		1247b.		1247c.		1248a.		1248b.		1248c.	
Wave-Length.		Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.
4861·527		1	20·61	1	33·67	1	16·25	½	49·78	1	12·63	1	33·09
4481·400		3	50·64	3	50·29	3	40·28	2	24·28	1	8·17	2	58·12
4471·676		2	37·40	2	61·06	2	41·51	1	22·53	1	27·10	2	53·75
4340·634		2	34·13	3	41·43	3	31·83	3	36·32	3	28·49	3	52·[illegible]
4102·000		1½	33·07	2	20·74	2½	42·44	2	29·16	2	26·12	2	34·32
4026·352		½	60·38	½	27·99	1	25·96	2	45·08	½	33·12	1	49·56
3933·825		1	48·24	1	53·25	1	53·48	1	59·99	1	50·63	1	54·37
Wt'd. Mean.	All Lines..	40·34		43·17		37·12		35·95		26·61		49·77	
	Three Lines..	42·14		49·66		37·42		30·01		24·15		54·51	

THREE PRISM, CAMERA 525 mm. FOCUS.

Slit 0·025.

Plate No.	1405.		1406.		1407.		1408.		1409.		1410.	
Wave-Length.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.
4861·527	1	35·59	1	39·55	1	39·55	1	37·52	1	34·02	1	35·36
4481·400	2	52·05	2	53·33	3	46·96	2	47·17	2	51·39	2	49·81
4471·676	1½	52·00	1½	47·33	1½	52·98	1½	54·70	1½	58·30	1½	47·91
4388·100	1	54·44	1	50·53	1	41·04	1	54·99	1	54·89	½	45·13
4340·634	2	44·48	1½	46·76	2	41·66	1½	49·58	2	51·33	2	47·82
4131·047	¼	51·52	¼	37·91	1	47·05	¼	52·15	½	49·09	¼	44·56
4128·211	½	41·67	¼	50·97	½	57·23	½	47·85	½	47·85	¼	53·58
4102·000	1	30·55	1	32·73	½	42·65	½	36·15	½	39·61	¼	35·08
Wt'd. Mean. Four Lines	50·08		49·72		45·96		51·16		53·50		48·28	
Wt'd. Mean. Three Lines	49·28		49·58		46·72		50·15		53·25		48·57	

Slit 0·038.

Plate No.	1411.		1412.		1413.		1414.		1420.		1432.	
Wave-Length.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.
4861·527	1	25·63	½	54·17	1	32·15	½	35·53	1	44·56	1	65·19
4481·400	3	48·95	3	49·60	3	52·83	3	50·02	3	47·75	3	43·94
4471·676	1½	52·94	2	55·18	1½	50·73	2	53·38	2	45·20	2	38·25
4388·100	½	49·16	1	39·44	½	44·24	½	34·03	½	43·27	1	39·92
4340·634	2	45·64	2	46·06	2	54·50	2	54·40	1½	44·02	2	52·56
Wt'd. Mean. Four Lines	48·87		48·84		52·24		51·02		45·90		44·17	
Wt'd. Mean. Three Lines	48·85		50·18		52·86		52·23		46·10		44·78	

THREE PRISM, CAMERA 525 mm. FOCUS.

Slit 0·051.

Plate No.		1426.		1427.		1428.		1429.		1430.		1431.	
Wave Length.		Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.
4861·527		1	45·15	1	49·46	1	58·14	1	40·14	1	45·96	1	47·36
4481·400		2	40·35	2	41·09	2	40·01	2	42·21	2	41·17	2	40·14
4471·676		1½	43·98	1	46·35	1½	44·80	1½	48·89	1½	45·41	1½	37·84
4388·100		½	33·96	½	33·20	½	38·62	1	46·25	½	33·52	½	33·22
4340·634		1½	49·05	2	50·45	2	47·47	2	46·06	1½	45·18	2	50·81
Wt'd. Mean.	Four Lines	43·14		44·73		43·58		45·56		42·72		42·54	
	Three Lines	44·05		45·89		44·03		45·43		43·64		43·39	

Slit 0·076.

Plate No.		1433.		1434.		1435.		1436.		1437.		1438.	
Wave-Length.		Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.
4861·527		1	48·30	1	36·76	1	47·60	1	42·17	1	33·03	1	40·37
4481·400		2	41·84	2	40·76	2	38·15	2	39·60	1½	41·17	1½	40·54
4471·676		1½	43·16	1	51·30	1	43·32	1½	37·68	1	44·39	1	47·46
4388·100		½	39·92	½	45·32	½	29·79	½	23·90	½	47·63	½	26·10
4340·634		2	42·23	1	45·88	1½	42·93	1½	49·40	2	44·83	1½	44·48
Wt'd. Mean.	Four Lines	42·14		44·75		39·78		40·32		43·92		41·80	
	Three Lines	42·31		44·68		40·89		41·96		43·51		43·75	

THREE PRISM, CAMERA 275 mm. FOCUS.

Slit 0·025.

PLATE No.	1285a.		1285b.		1285c.		1286a.		1286b.		1286c.	
Wave-Length.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.
4861·527	½	12·30	1	13·74	1	43·11	1	40·89	½	14·41	1	15·84
4481·400	2	35·17	2	31·88	2	31·43	2	42·73	2	41·16	2	44·90
4471·676	1½	39·88	1	51·53	2	44·62	2	43·36	1½	39·21	2	46·68
4340·634	1½	32·61	1½	42·20	1½	42·83	1½	38·69	1½	36·50	2	43·02
4131·047	1	33·79	½	47·52	1	39·32	1	35·63	1	36·87	1½	43·50
4128·211	1	38·41	½	40·68	1	40·41	½	38·68	1	36·29	1	38·57
4102·000	1	28·87	1	32·26	1½	19·25	1	33·31	1½	25·85	1	19·52
Wt'd. Mean. All Lines	33·68		35·83		36·79		39·93		35·00		38·89	
Wt'd. Mean. Five Lines	35·90		40·49		39·48		40·74		38·43		43·88	
Wt'd. Mean. Three Lines	35·82		39·69		39·34		41·76		39·19		44·87	

THREE PRISM, CAMERA 275 mm. FOCUS.

Slit 0·051.

Plate No.		1289a.		1289b.		1289c.		1290a.		1290b.		1290c.	
Wave-Length.		Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.
4861·527		½	5·32	1	20 17	1	55·41	1	45·21	½	26·60	1	36 79
4481·400. ...		2	46·92	3	36·07	3	45 05	3	37·56	3	48·04	3	38 31
4471·676.		1½	35·07	2	45·21	2	48·54	...	......	2	39·21	1½	43·65
4340·634 .		3	34 99	3	41·70	3	51·11	2	34·24	2	36·37	3	31·54
4131 047		1	29 09	½	28 35	1	37·11	½	46·41	½	46 60	¼	44 52
4128·211..		1½	37·97	½	34·08	½	36·28	½	37 19	¼	48·66	½	38·48
4102·000.. ...		1½	28·68	1	32·55	½	21·11	½	22·95	½	30·86	1	25·14
Wt'd Mean.	All Lines..	34·83		37 06		46·07		37·29		41·08		35·83	
	Five Lines	37·49		39·47		46·40		37·16		42 67		37·02	
	Three Lines..	38·68		40·47		48·19		36·23		42·18		36·67	

Slit 0·076.

Plate No.		1291a.		1291b.		1291c.		1292a.		1292b.		1292c.	
Wave-Length		Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.
4861·527....		1	32·03	½	46·32	½	42·67	1	5·54	1	71·81	1	57·18
4481·400		2	38·16	2	36·66	1½	24·09	2	35·17	2	45·79	2	39·06
4471·676.		1½	39·29	1½	38·55	1½	38·18	1½	43·77	1½	40·03	1½	49·65
4340·634..		2	42·96	1½	36·18	1½	25·46	1½	28·34	1½	29·91	1½	27·34
4131·047.. .. .		½	46·74	½	39·18	½	37·61	¾	36·65	½	43·05	1	48·90
4128·211		½	33·53	½	33·66	1	32·70	¼	55·55	¼	46·55	1	45·22
4102·00....		½	23·12	1	28·66	1½	29·89	1	18 06	1	26·94	1	29 98
Wt d. Mean .	All Lines..	38 11		36·49		31·16		30·43		42·37		41·65	
	Five Lines..	40·20		36·97		30·52		36·64		39·91		41·10	
	Three Lines..	40·21		37·08		29·25		35·70		39·30		38·72	

As previously mentioned, in order to get the probable error of the velocity determination from a single line when, as in this case, six plates are used, it appears preferable to use the weighted residuals from the mean velocity for each plate rather than the residuals from the mean velocity of all six plates. The former method frees the determination from any chance of disturbance by systematic displacement of the star lines with respect to the comparison lines on any of the plates. Some idea of the magnitude of the latter error may be obtained by combining the residuals obtained by subtracting the velocity value of each plate from the mean of the six. But this will be affected also by the accidental errors of the separate plates and, moreover, there are not enough measures to give any definite result. However, this will also be obtained and, as will be seen, may be used in a comparative way for the different slit widths.

The probable errors of setting on a single line are obtained from two or three groupings of the lines in each dispersion. In dispersion (*a*) 1st from all seven lines. 2nd from the three lines. *Mg* 4481, *He* 4471 and $H\gamma$ 4340; in dispersion (*b*), 1st from the four lines 4481, 4471, 4388 and 4340. 2nd from the three 4481, 4471, 4340; in dispersion (*c*) 1st from all the lines measured. 2nd from the five lines 4481, 4471, 4340, 4131, 4128. 3rd from the three lines 4481, 4471, 4340. The three lines 4481, 4471, 4340 are by far the best on the plates and their measures deserve much higher weight, not only on account of their quality, but also because they are near the position of minimum deviation λ 4415, the axis of the camera lens, and the minimum focus of the colour curve of objective and corrector. As will be seen below, the probable errors are considerably smaller when these three lines only are used than when some of the poorer lines are combined with them.

The probable errors obtained by these different groupings are tabulated below:—

DISPERSION (*a*).

SINGLE PRISM.—CAMERA 525 MM. FOCUS.

Probable Error of Setting on a Single Line.

Slit-Width in mm.	Probable Error. 7 Lines, 42 Residuals.	Probable Error. 3 Lines, 18 Residuals.
0·025	± 5·3 km.	± 4·5 km.
0·038	4·8	2·4
0·051	5·2	2·3
0·076	7·5	4·3

PROBABLE ERROR, SINGLE PLATE.

Residuals from Six Plates.

Slit-Width in mm.	Probable Error. Velocities from 7 Lines.	Probable Error. Velocities from 3 Lines.
0·025	± 1·3 km.	± 1·7 km.
0·038	2·5	2·7
0·051	1·5	3·0
0·076	5·2	7·7

DISPERSION (a)—*Continued.*

MEAN VELOCITIES—REDUCED TO SUN.

Slit-Width.	Velocities from 7 Lines.	Velocities from 3 Lines.
0·025	+ 21·4 ± 0·5	+23·2 ± 0·7
0·038	19·7 ± 1·1	22·8 ± 1·0
0·051	18·2 ± 0·6	20·2 ± 1·2
0·076	20·4 ± 2·1	21·2 ± 3·2

DISPERSION (b).

THREE PRISMS — CAMERA 525 MM. FOCUS.

Probable Error of Setting on a Single Line.

Slit-Width in mm.	Probable Error. 4 Lines, 24 Residuals.	Probable Error. 3 Lines, 18 Residuals.
0·025	± 2·3 km.	± 2·3 km.
0·038	2·8	2·1
0·051	3·0	2·5
0·076	3·1	2·1

PROBABLE ERROR, SINGLE PLATE.

Residuals from 6 Plates.

Slit-Width in mm.	Probable Error. Velocities from 4 lines.	Probable Error. Velocities from 3 lines.
0·025	± 1·7 km.	± 1·5 km.
0·038 — 4 plates.	1·2	1·3
0·038 — 6 plates.	2·1	2·2
0·051	0·8	0·7
0·076	1·4	0·9

MEAN VELOCITIES — REDUCED TO SUN.

Date.	Slit-Width in mm.	Velocities from 4 lines.	Velocities from 3 lines.
Mar. 20	0·025	+ 24·5 ± 0·7	+ 24·3 ± 0·6
" 20	0·038—4 plates.	24·9 ± 0·5	25·7 ± 0·5
" 21	0·038—1 plate.	20·8	21·0
" 24	0·038—1 plate.	+ 19·4	19·9
" 24	0·051	18·9 ± 0·3	19·6 ± 0·3
" 24	0·076	16·1 ± 0·6	18·0 ± 0·4

DISPERSION (*c*).

THREE PRISMS — CAMERA 275 mm. FOCUS.

Probable Error of Setting on a Single Line.

Slit-Width in mm.	Probable Error. 7 Lines, 42 Residuals.	Probable Error. 5 Lines, 30 Residuals.	Probable Error. 3 Lines, 18 Residuals.
0·025	±5·6 km.	± 2·8 km.	± 2·9 km.
0·051	4·8	3·2	2·9
0·076	6.4	4·0	3·8

PROBABLE ERROR, SINGLE PLATE.

Residuals from 6 plates.

Slit-Width in mm.	Probable Error. Velocities from 7 Lines.	Probable Error. Velocities from 5 Lines.	Probable Error. Velocities from 3 Lines.
0·025	± 2·4	±3·2	± 2·1
0·051	4·2	3 8	3·0
0·076	5·0	3·8	2·9

MEAN VELOCITIES — REDUCED TO SUN.

Slit-Width in mm.	Velocities from 7 Lines.	Velocities from 5 Lines.	Velocities from 3 Lines.
·025	+16·2 ± 1·0	+21·0 ± 1·3	+ 19·6 ± 0·9
·051	18·1 ± 1·7	19·4 ± 1·5	19·8 ± 1·2
076	16·1 ± 2·1	16·9 ± 1·5	16·1 ± 1·2

The above summary of the measures and probable errors shows some curious and even unexpected results.

With the single prism spectrograph, the probable error of setting does not increase very markedly as the slit is increased in width from 0·025 to 0·051 mm., but a further increase to 0·076 mm. makes a marked increase of about 50 per cent in the accidental errors. The systematic errors show an even more marked increase, of about 3 times, when the slit is made 0·076 mm. wide. This is, in this case, undoubtedly caused by the fact that the centre of intensity of the star image was not symmetrically situated between the slit jaws and consequently the position of the lines was similarly displaced from the centre. The experiments detailed under the heading 'New Correcting Lens' showed that the star image had a minimum effective diameter of about 0·050 mm., which is, however, increased by increased exposure. In the present case, as the exposure was only about 30 seconds, it is probable that, during an exposure, the star image was not on the whole central causing the lines to be displaced and the measured velocity to vary. A non-central position of the image to the amount of ·004 mm. would cause an error of about 10 kms. in the velocity. Undoubtedly, if the exposure had been longer, the vagaries of seeing and guiding would ensure a mean position very nearly central, and the systematic displacement or error would be considerably reduced. This is well shown in dispersion (*c*) and (*b*)

where the exposures were about 2 and 5 minutes respectively. In (b) especially the results show no evidence whatever of systematic error, on the contrary the probable error of a single plate is smaller for slit 0·076 mm. than for slits 0·025 and 0·038 mm. In this connection, it may be of interest to point out the systematic differences between the mean velocities obtained with wide and narrow slits. They show, on the whole, a smaller positive value (leaving dispersion (b) out of account for a reason to be stated later on) of about 2 kms. for the wider slit widths. This may be due to a sort of personal error in guiding, caused either by habit or by some peculiarity in the optical path from the slit to the eye, which systematically causes the image to be placed to one side of the centre of the opening.

With the three prism spectrograph and the 525 mm. focus camera, the probable errors due both to systematic displacements and accidental errors of setting do not, on the whole, indicate any increase in error with increase in slit width, and so far as stars of this type are concerned one should, if these results can be depended on, get as accurate measures and as reliable results with a slit 0·076 mm. wide as with a slit 0·025 mm. As the exposure time required for the former width is only about one-third that for the latter, this means a very considerable increase in the output of the installation. The measures show that the residuals and probable errors from the single plates are smaller with slit 0·051 and 0·076 mm. than with slit 0·025 and 0·038 mm. I cannot assign any reason for this apparently improbable result.

In the table of velocities reduced to the sun for this dispersion it will be noticed there is a large systematic difference in the mean values between slit widths 0·025, 0·038 and slit widths 0·051 and 0·076. This difference may be partly assigned as above, but its amount seems too large, considering that each velocity given is the mean of six plates. As these plates were exposed on different dates, one explanation of the cause might be a variable radial velocity of the star, but no positive statement can be made without further proof. This explanation seems plausible when we look at the velocities for slit width 0·038 mm., which were made on three different dates. Four plates made on Mar. 20 give a mean velocity of 24·9 kms., with a total range between highest and lowest of 3·4 kms. One plate on March 21 at same slit width gave a velocity of 20·8 and one on March 24 of 19·4. These figures are for 4 lines: λ 4481, 4471, 4388, 4340. For the three principal lines the respective figures are 25·7, with total range of 4·0, 21·0 and 19·9, respectively. The mean of 10 plates on March 20 is 24·7 and 25·0 for 4 and 3 lines, respectively, and of 12 plates on March 24, 17·5 and 18·8 for 4 and 3 lines. The probable error of a single velocity deduced from these two means is nearly $\mp$ 1·3 kms. for each set. So that, considering plates either at the same or different slit widths, there appears to be a change in the velocity which, if there is no systematic cause for the change, must be real. The matter, however, will be investigated further, using, as nearly as possible, similar conditions of exposure slit width, &c.

With a dispersion of three prisms and the Ross Homocentric Camera lens of about 275 mm. focus, the increase in probable error of setting on a single line increases with the slit width, but not to any considerable extent, as the above summary of the probable errors shows. Also the change in the probable error of a single plate is not very great, indicating no decided systematic displacement with the wider slits. However, as mentioned above, the lens has some aberration and this, with the fact that no temperature regulation could be used, diminishes the value of the results.

Summarizing the whole investigation, we may conclude with confidence that a slit of at least 0·051 mm. wide may be used on early type stars without appreciably increasing the errors of setting on the lines or introducing any systematic displacement. In the case of the higher dispersions, the slit may be widened still further to 0·076 mm. without, in the case of β Orionis, at any rate, appreciably diminishing the accuracy of velocity determinations. This may also possibly be true in single prism work with faint stars where the exposure will be longer than a few minutes. It

must not, however, be forgotten, if the spectrum has faint metallic lines, as is the case with Sirius and Vega, that an increase in slit width will undoubtedly diminish the contrast, and with a slit as wide as 0·076 mm. cause the fainter lines to disappear.

Some other interesting and useful points may also be obtained from these measures and from a study of the residuals from the various lines. The wave length of $H\delta$, which had already been changed from Rowland's value of 4102·000 to 4101·890 by measures by Campbell & Wright,* was determined from the residuals obtained from 18 plates with the single prism and 12 with the three prism spectrograph. The mean residual, using wave length 4102·000, is for single prism plates + 10·6 kms. and three prism plates with short focus camera + 12·2 kms. The weighted mean of these two is + 11·2 kms., which corresponds to a change in wave length of 0·152 tenth-metres, making the wave length as determined from β Orionis 4101·848. This, however, is not to be taken as a correction to 4101·890, but rather as an indication that the wave length as given by Rowland, when used in velocity determinations with first type stars, will give a positive residual of about 10 kms.

Another very useful point obtained from a study of the residuals of $H\beta$ in all the dispersions is that velocity values obtained from this line are not reliable and that it would be preferable to omit it in the measurement of all plates. The residuals are mostly positive, but there are also some high negative values and apparently no confidence can be placed in the results obtained from it. These discrepancies occur in all three dispersions, and a definite cause can undoubtedly be assigned for them. At $H\beta$ the star image is out of focus, owing to the form of colour curve of objective and corrector, to the extent of about 4 mms. when it is in focus at λ 4415, and in consequence the image is an expanded disc more than a quarter of a millimetre in diameter. Only part of the light from the objective can get through the slit, and the illumination on the collimator and camera lens is a comparatively narrow bar parallel to the slit which changes in position with change of guiding and which is rarely central. Even if it were central on the collimator, the vignetting of the pencil away from the centre of the field by the prisms would disturb this central position on the camera. Whenever the plate is not in exact focus at the region in question, a systematic shift of the star line with respect to the comparison lines whose illumination is always uniformly distributed would occur. The camera lenses employed give a field almost flat but it is quite possible for a deviation from focus of 0·1 or 0·2 mm. to occur. Supposing the centre of intensities of star and comparison light were distant from one another, say 10 mm., this would cause a relative displacement of $\frac{0\cdot2}{525}\times 10 = \cdot004$ mm. equivalent with the single prism instrument to about 12 kms. In the case of dispersion c the deviation from focus owing to the aberrations of the lens is much greater and so also are the residuals, while in dispersion b the residuals are least, as a given linear displacement corresponds to a kilometre value only one-third as great.

In the case of lines to the violet end of the field, the residuals do not indicate any systematic difference, nor are they of a greater magnitude than is to be expected from their character. In this case, the star focus for the wave lengths in question $H\delta$ to $H\epsilon$ and K is, even in the extreme case of $H\epsilon$ and K, only about 2 mm. beyond the focus for λ 4415, and the illumination in consequence is so much more uniform that, when the plate is in good focus, no systematic displacement is to be feared. Furthermore, a given linear displacement in this region would, owing to the change in dispersion, correspond to only one-half the kilometre value of the $H\beta$ region.

RADIAL VELOCITIES.

The work in determining radial velocities has been actively prosecuted during the period which this report covers. It may be of interest to give some numerical

* Astrophysical Journal IX, p. 50.

data in regard to the progress of the work. During the year ending March 11, 1908, 736 stellar spectrograms have been made on 138 nights. Of these 438 have been measured. Want of sufficient assistance is the principal cause for the non-measurement of the remainder, but other reasons apply in the case of some plates. Some of the spectra are too weak or otherwise unsuitable for measurement; some are of binary stars on which work has been abandoned because of too small range in velocity accompanied by poor quality of spectrum for measurement; some are experimental or test plates. Of the measured spectra upwards of three-fourths are of known spectroscopic binaries. Only about half of these have been used in the determination of the completed or provisional orbits discussed below, the remainder being measures of binaries of which sufficient observations have not yet been obtained to determine the orbits. Of the remaining measures (over 100) nearly 70 of β Orionis have been made for the purpose of determining the relative accuracy obtained by the use of different slit-widths. Some are of suspected binaries and some of early type stars not hitherto observed. Of the suspected binaries, special mention should be made of η Piscium of which a number of plates made by the Brashear Spectroscope have been measured. These showed that there was some little range in the star's velocity. However, poor temperature regulation led to systematic errors in some plates made by this instrument, and there was consequently some uncertainty as to the variability of its velocity. A number of plates made since with the new three prism spectrograph show a small change in the radial velocity, the variation so far observed being about 6 kms. from +12 to +18 kms. per second. Observations on this star will be continued when it has sufficiently passed conjunction to enable it to be readily observed.

Spectroscopic Binaries.

The spectroscopic binaries which have been under observation here during the above period are as follows:—

τ Tauri.	η Bootis.
ψ Orionis.	α Coronæ Borealis.
ι Orionis.	
B. D. – 1° 1004.	ϵ Herculis.
ν Orionis.	δ Aquilae.
γ Geminorum.	θ Aquilae.
ω Ursae Majoris.	
93 Leonis.	o Andromedae.
η Virginis.	

Of the above, ι Orionis and ψ Orionis have been completed and provisional orbits have been obtained for η Virginis and θ Aquilae. o Andromedae has been abandoned as the range is too small, considering the character of the spectrum, to allow its orbit to be determined. Only a few observations of ω Ursae Majoris, 93 Leonis and ϵ Herculis have yet been obtained. Of the others, a number have been obtained, but not sufficient to determine even preliminary elements. There is a great difference in the amount of observational material necessary to obtain the elements of the orbit in different stars. If the spectrum is of the solar or allied type, where accurate measures can be obtained, usually few, twenty or thirty, observations will suffice, while if it is of an early type, particularly if the lines are diffuse and the total range of velocity small many more are required. For example, 107 measures were used in the determination of the elements of ι Orionis, which is, however, perhaps an exceptional case, owing to the very diffuse lines and the high eccentricity of the orbit with the consequent difficulty in covering the rapidly descending branch and the maximum and minimum points of the curve.

In determining the elements of the binaries various methods have been used, but the quality of the spectra for measurement has never been good enough to allow of a better than rough determination by any of the usual methods, Lehmann-Filhés',

Russell's, Schwarzschild's or Zurhellen's. It has always consequently been necessary to correct the preliminary determinations by a species of trial and error. By constructing ephemerides and drawing the velocity curves for different sets of elements near those determined, we can obtain the curve most nearly agreeing with the observations. A little experience in the character of the changes produced in the velocity curve by changes in e and ω soon enables the labour to be shortened.

The method developed by you for obtaining the elements of the orbit, particularly its application in constructing an ephemeris, also much shortens the labour in such a process of trial and error. The time required to plot a velocity curve from any given elements is, by your method, less than half an hour, while any other method, even with the aid of suitable tables, will require two or three hours. The protractors necessary in the use of the method were carefully constructed by Mr. Gauthier, on thin transparent celluloid, the angles being computed by Mr. Motherwell from Astrand's tables. Protractors for every value of e between 0 and 1 by intervals of 0·05 were made and their accuracy with the fineness of the lines enables very accurate ephemerides to be constructed, with no computation whatever.

Of the four orbits given below the elements of ι Orionis and ψ Orionis were obtained by myself, while those of θ Aquilae and η Virginis were determined by Mr. Harper, who has written the description of his work, which appears below. Curiously enough, as will be seen in the detailed measures, most of the measurement on ι Orionis is by Mr. Harper and on η Virginis by myself.

ι Orionis.

This star – R. A. 5 h. 30·5 m., Decl. – 5° 59′, Photographic Magnitude 3·4 was announced by Frost & Adams* as a spectroscopic binary. It was placed under observation here for the determination of its orbit in December, 1906. Of the 107 plates used for this purpose 37 were made between December 11, 1906, and April 11, 1907, the remaining 70 between September 14, 1907, and January 25, 1908. The first series was made with the adapted Brashear spectroscope and the measures, along with a velocity curve for a period of 29·128 days were published in last year's report. The last series was made with the new single prism spectrograph and the detailed measures are given below.

The linear dispersion of the Brashear instrument is 18·6 and of the single prism spectrograph 30·2 tenth-metres per mm. at $H\gamma$. Notwithstanding the greater dispersion of the former instrument more confidence should be placed, in the case of this star, in the results obtained by the latter for two reasons. With the former instrument, owing to curvature of field of the camera lens, only two lines He 4471 and $H\gamma$ 4340 are accurately measurable, while with the latter all the lines, usually five or six from $H\beta$ to $H\epsilon$ inclusive are available. In the second place, on the broad and diffuse lines of this spectrum, the settings can be more accurately made when photographed with the smaller dispersion.

The spectrum is of the helium type, the lines used for determining the velocity being given in the table below.

Lines in Spectrum of ι Orionis.

Elements.	Wave Length.
$H\beta$	4861·527
He	4713·308
He	4471·676
He	4388·100
$H\gamma$	4340·634
$H\delta$	4102·000
He	4026·352
$H\epsilon$	3970·177
Ca	3933·825

* Astrophysical Journal XVIII., p. 386.

The lines λ 4713, 4388 and 3933 are rarely measurable or even visible on the plates, and consequently they have only been used a few times. The other six lines have been nearly always used in the single prism plates. Lines of wave lengths λ 4686, 4543, 4143 and 4089 have been seen on some plates but never used in the velocity determination. All the lines, as stated above, are very broad and diffuse, the widths varying between 2 and 4 tenth-metres. They are in many cases so faint as to be only with difficulty distinguished from the adjacent continuous spectrum. The difficulty of setting is further increased by the asymmetry of many of the lines, this asymmetry combined with their diffuse character, rendering the settings uncertain. A peculiarity about this asymmetry is that all the lines of a spectrum are not necessarily affected in the same way. Some may have the maximum intensity to the red and some to the violet side of the band, while other lines may be nearly uniform. Although in one or two cases some of the lines appear doubled, this is by no means a common characteristic, and this apparent doubling should not necessarily be assigned to the presence of a second spectrum, but possibly to some irregular arrangement of the silver grains in the naturally broad diffuse and asymmetric lines of the spectrum or to some physical effect in the star's atmosphere. No evidence of the triple superposed maxima observed by Frost and Adams has been found on any of the plates, but this may possibly be due to the lower dispersion used here.

In consequence of the poor quality of the lines for measurement, the radial velocities obtained may, in some cases, be in error to the extent of 15 or 20 kms. per sec. Occasionally in two plates made on the same night there has been a difference of upwards of 30 kms. in the measured velocity. That this difference is in great part due to the character of the lines is shown by the fact that measures of the same plates by different observers occasionally differ about 20 kms. in the velocity. The probable error of a single plate, obtained by the use of the residuals from the final curve of oscillation, is for the Brashear spectroscope plates ± 7·8 kms. per second, and for the single prism plates ± 6·6 kms. per second.

It is only when the range of velocity is large (in this case about 225 kms.) and where a large number of spectra have been secured, that a satisfactory orbit can be obtained for stars with this type of spectrum. The difficulty is, in the present instance, probably increased by the high eccentricity of the orbit and consequently abruptly changing form of the velocity curve, as well as by a probable secondary disturbance giving rise to a secondary curve superposed upon the primary.

The early observations with the Brashear spectroscope indicated a period of about 29 days. When use was made of Frost's and Adams' observations of 1903, the period was approximately determined as 29·128 days. When all the observations were brought into one period, it was at once seen that plates were required at the maximum and minimum points and along the rapidly descending branch of the curve, about 4 days out of the 29. Cloudy skies at every recurrence of this epoch prevented these being secured during the winter of 1906-7, and it almost seemed the same bad fortune was to prevail in 1907-8. Although partial success was obtained in October, 1907, it was not until January 24 and 25, 1908, that the final observations necessary were secured. The observations of October indicated a period of 29·134 days, but the later plates changed this to 29·136 days. This can hardly be in error more than the thousandth of a day, as it is determined by the coincidence of an observation of Frost's and Adams' on September 5, 1903, with the rapidly descending branch as finally defined on January 25, 1908, 55 periods distant.

Originally each single measurement was plotted on cross-section paper, but the confusion and overlapping resulting as the number increased rendered necessary the combining of those made on the same night (sometimes five in number at critical parts of the curve) into a mean, weighted according to the quality of the plates. The observations reduced according to this plan with the velocity curve finally chosen are shown in Fig. 4, where the single circles represent single observations and the double circles two or more observations on the same night. It will be noticed in this figure

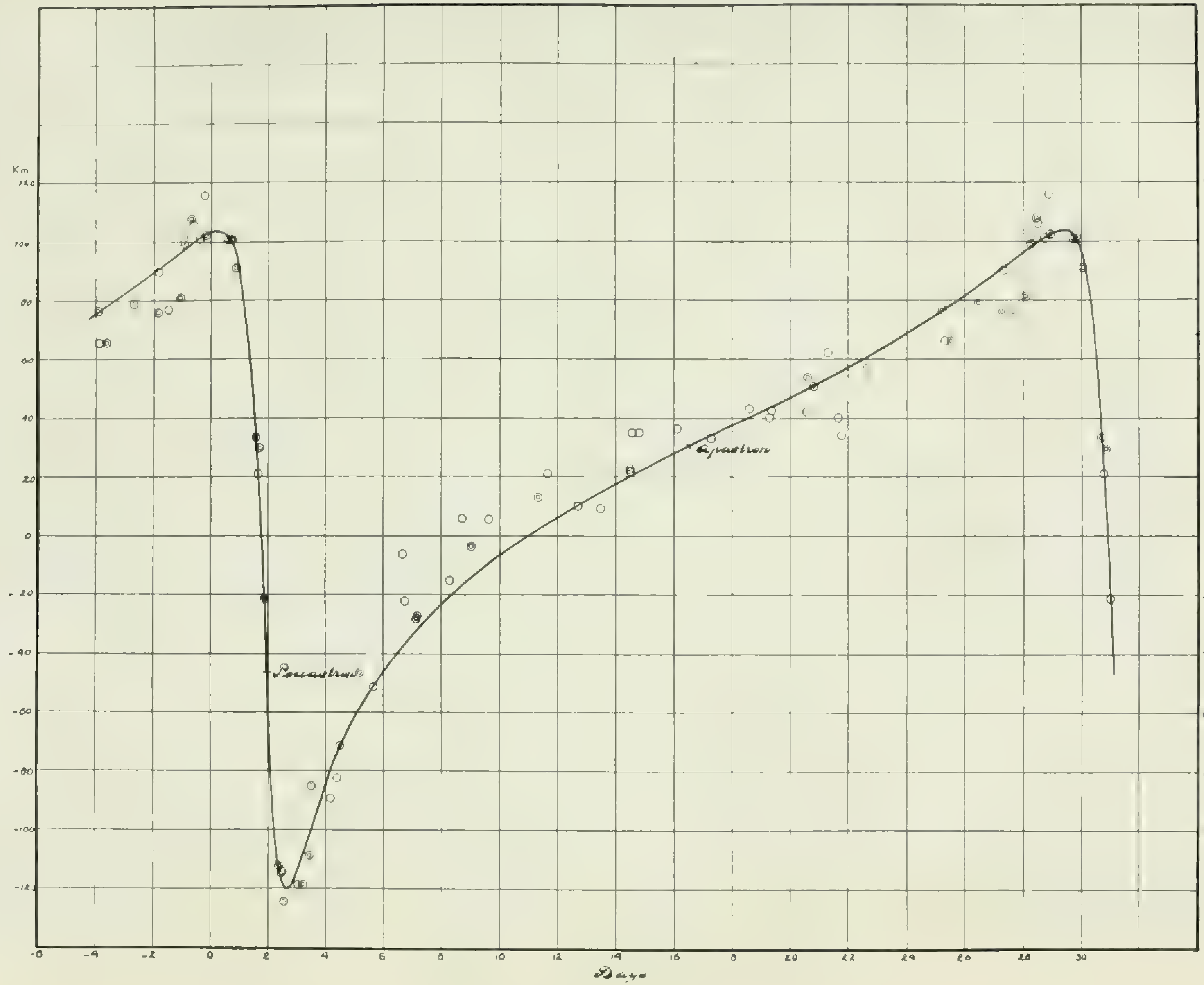


Fig. 4—Velocity Curve of ι Orionis.

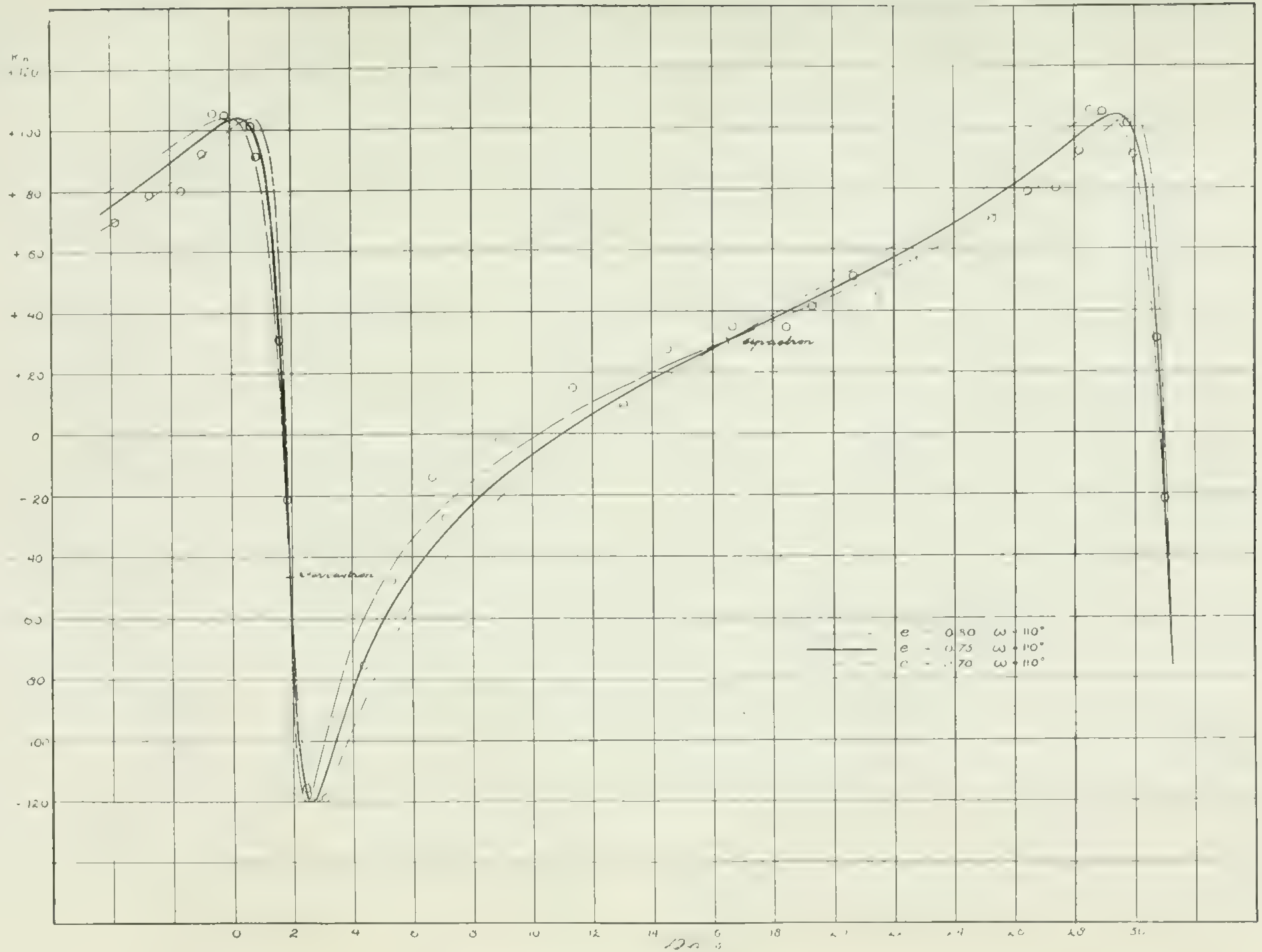


FIG. 5. Velocity Curve of ι Orionis.

that two or more single or grouped observations frequently occur at nearly the same phase, and it was felt that a further combining of the observations into those of nearly the same phase, after the period had been accurately determined, might be of advantage. The 107 observations made at Ottawa with the 6 made at the Yerkes Observatory were accordingly combined into 27 groups, with an average of slightly over 4 observations each. The effect of this grouping is shown in Fig. 5. The effect of large accidental errors in the velocity values of some of the plates is diminished and the drawing of the curve facilitated. In thus combining the observations, there are only two groups (near apastron where the change of velocity is slow) in which the difference of phase exceeds a day. The difference in the remainder is less than half a day, and in most of these (all around periastron) less than a quarter of a day.

It will be preferable before proceeding to determine the elements to give the measures of the last series of 70 plates, those of the first series being given last year. The journal or record of observations containing the data as to time, temperature, focus, &c., of the plates will first be given and this will be followed by the detailed measures. Several of the plates have been measured by two and some by three observers. All of these measures are given below and a comparison will enable some idea to be obtained of the uncertainty of the measures, and the difficulty in obtaining a satisfactory orbit. A table containing a summary of these with the earlier measures here and also of those previously made at the Yerkes Observatory is next given. In this table is contained the number of the plate, the date, the Julian day, the velocity, including all measures of the same plate, the measurer, the weighted mean of all measures of all plates on the same night, the phase, and the residual obtained by subtracting each measure from the value computed from the finally accepted elements. This table is followed by the one containing the observations grouped into phases, the velocity and phase of each group being the mean of the separate observations.

RECORD OF SPECTROGRAMS.

Star.	No. of Negative.	Camera.	Plate.	Date.	Middle of Exposure E. S. T.	Duration.	Hour Angle at end.	Comparison Spectrum. Exposures in seconds.	Comparison Spectrum. Kind.	Temperature Centigrade. Room. Beginning.	Room. End.	Prism Box. Beginning.	Prism Box. End.	Slit Width.	Focal Position. Star Focus.	Collimator.	Camera.	Seeing.	Observer.	Remarks.
				1907.	h. m.	m.	h. m.													
ι Orionis	1046	II.	Seed 27.	Sept. 14	3 35	20	2 15 E.	6 5 5	Fe. V. Spark.	19·1	19·0	20·8	20·8	·0011	73·0	10·8	18·6	Very unsteady.	P	
"	1059	"	"	" 18	5 16	18	0 23 E.	6 9 6	"	9·0	9·0	17·0	17·1	·0014	44·7	10·8	18·41	Fair to good.	H	
"	1069	"	"	" 20	4 19	22	1 10 E.	11 11	"	18·7	17·0	22·5	22·5	·0014	41·7	10·8	18·4	Fair..	T	
"	1070	"	"	" 20	4 41	22	0 15 E.	11 11	"	17·0	16·5	22·5	22·4	·0014	44·7	10·8	18·4	Good	T	
"	1076	"	"	" 30	4 18	21	0 32 E.	10 10	"	7·5	7·5	13·1	13·1	·0014	73·0	10·8	18·18	Fair..	T	
"	1077	"	"	" 30	4 12	25	0 05 E.	10 10	"	7·5	7·5	13·1	13·1	·0014	73·0	10·8	18·18	"	T	
"	1078	"	"	" 30	5 05	19	0 15 W.	10 10	"	7·0	5·0	13·1	13·1	·0014	73·0	10·8	18·18	"	T	
"	1079	"	"	" 30	5 28	24	0 36 W.	10 10	"	5·0	4·9	13·1	13·1	·0014	73·0	10·8	18·18	"	T	Daylight.
"	1097	III.	"	Oct. 8	3 22	45	0 44 E.	17 17 17	"	1·8	1·1	9·8	9·8	·0016	72·0	10·8	5·15	Good	T	
"	1108	II.	"	" 28	5 34	25	2 39 W.	8 12 8	"	3·0	2·5	8·7	8·6	·0014	72·5	10·8	18·2	Fair..	H	
"	1109	"	"	" 28	6 03	29	3 10 W.	8 8 8	"	2·5	0·0	8·6	8·5	·0014	72·5	10·8	18·2	Poor	H	Made in daylight
"	1110	"	"	" 29	3 27	26	0 35 W.	8 8 8	"	1·0	1·0	4·5	4·5	·0014	72·5	10·8	18·08	Unsteady.	H	
"	1111	"	"	" 29	3 56	28	1 05 W.	8 8 8	"	1·0	0·0	4·5	4·5	·0014	72·5	10·8	18·08	"	H	
"	1112	"	"	" 29	4 26	31	1 35 W.	8 8 8	"	0·5	−0·5	4·5	4·4	·0014	72·5	10·8	18·08	"	H	
"	1113	"	"	" 29	4 58	33	2 10 W.	8 8 8	"	0·5	−1·0	4·3	4·1	·0014	72·5	10·8	18·08	"	H	
"	1114	"	"	" 29	5 43	30	2 53 W.	8 8 8	"	1·0	−1·0	4·1	4·2	·0014	72·5	10·8	18·08	"	H	Daylight.
"	1115	"	"	" 30	1 42	25	1 07 E.	3 8 3	"	1·0	0·0	2·3	2·3	·0014	72·5	10·8	18·08	Good	H	
"	1116	"	"	" 30	2 12	30	0 35 E.	3 8 3	"	0·0	0·0	2·3	2·3	·0014	72·5	10·8	18·08	"	H	
"	1117	"	"	" 30	2 47	35	0 03 W.	3 8 3	"	0·0	0·0	2·3	2·3	·0014	72·5	10·8	18·08	"	H	
"	1118	"	"	" 30	3 26	40	0 41 W.	3 8 3	"	0·0	0·0	2·3	2·3	·0014	72·5	10·8	18·08	"	H	
"	1119	"	"	" 30	4 09	42	1 28 W.	3 8 3	"	0·0	0·0	2·3	2·3	·0014	72·5	10·8	18·08	"	H	
"	1120	"	"	" 30	4 49	35	2 05 W.	3 8 3	"	0·0	−1·3	2·3	2·3	·0014	72·5	10·8	18·08	"	H	
"	1121	"	"	" 31	1 47	40	0 55 E.	4 6 4	"	3·3	2·7	7·7	7·7	·0012	72·6	10·8	18·12	Hazy..	P	Unsteady.
"	1122	"	"	" 31	2 15	40	0 05 W.	4 4 4 4	"	2·7	2·7	7·6	7·6	·0012	73·5	10·8	18·12	Poor.	P	
"	1123	"	"	" 31	3 40	60	1 10 W.	4 4 4 4	"	2·7	1·3	7·6	7·5	·0012	73·5	10·8	18·16	"	P	
"	1124	"	"	Nov. 1	1 35	40	1 00 E.	4 4 4 4	"	4·6	3·8	8·5	8·4	·0012	73·5	10·8	18·16	"	P	
"	1125	"	"	" 1	2 20	40	0 15 E.	4 4 4 4	"	3·8	4·4	8·4	8·3	·0012	73·5	10·8	18·16	"	P	
"	1126	"	"	" 1	3 00	30	0 20 W.	4 4 4 4	"	4·4	4·2	8·3	8·3	·0012	73·5	10·8	18·16	Better	P	
"	1127	"	"	" 1	3 23	10	0 35 W.	3 4 3	"	....	....							....	P	Clouded over.
"	1136	"	"	" 11	1 28	46	0 24 E.	6 4 10	"	1·0	−1·5	5·5	5·5	·0014	73·5	10·8	18·2	Hazy....	H	

"	..	1137	"	" ..	"	11	2	07	28	0 04 W.	6- 6-10	" ..	— 1·5	— 2·0	5·5	5·5	·0014	73·5	10·8	18·2	Good.....	H	
"	..	1141	"	" ..	"	15	1	02	15	0 50 E.	4- 8- 4	" ..	— 1·0	— 1·5	6·0	6·0	·0013	73·5	10·8	18·2	"	H	
"	..	1142	"	" ..	"	15	1	19	15	0 33 E.	4- 8- 4	" ..	— 1·5	— 2·0	6·0	6·0	·0013	73·5	10·8	18·2	"	H	
"	..	1143	"	" ..	"	15	1	36	16	0 15 E.	4- 8- 4	" ..	— 2·0	— 2·0	6·0	6·0	·0013	73·5	10·8	18·2	"	H	
"	..	1147	"	" ..	"	16	12	29	15	1 25 E.	7-10- 7	" ..	1·3	1·3	3·2	3·6	·0013	73·5	10·8	18·18	Fair.....	P	
"	..	1148	"	" ..	"	16	12	40	15	1 05 E.	8-12- 8	" ..	1·3	1·3	3·6	3·6	·0013	73·5	10·8	18·18	"	P	
"	..	1161	"	" ..	"	28	4	08	16	3 05 W.	3- 6- 3	" ..	— 4·0	— 4·1	— 1·8	— 1·8	·0014	74·0	10·8	18·18	"	P	
"	..	1162	"	" ..	"	28	4	30	20	3 25 W.	3- 6- 3	" ..	— 4·1	— 4·2	1·8	1·8	·0014	74·0	10·8	18·18	"	P	
"	..	1166	"	" ..	"	29	4	41	17	3 45 W.	3- 9- 5	" ..	— 5·0	— 5·5	5·0	4·8	·0013	74·0	10·8	18·18	"	H	
"	..	1167	"	" ..	"	29	4	58	13	4 00 W.	3- 9	" ..	— 5·5	.....	4·8	4·4	·0013	74·0	10·8	18·18	Hazy. ...	H	Stopped.
"	..	1168	"	" ..	Dec.	3	10	25	10	2 20 E.	8-15- 8	" ..	— 9·6	— 9·7	— 2·9	— 2·9	·0013	73·5	10·8	18·05	....	P	
"	..	1169	"	" ..	"	3	10	36	10	2 09 E.	8-15- 8	" ..	— 9·7	— 9·9	— 2·9	— 2·9	·0013	73·5	10·8	18·05	....	P	
"	..	1170	"	" ..	"	3	10	48	10	1 57 E.	8-15- 8	" ..	— 9·9	—10·1	— 2·9	— 2·9	·0013	73·5	10·8	18·05	....	P	
"	..	1178	"	" ..	"	14	12	27	10	0 13 E.	7-10	" ..	—12·0	12·0	0·7	0·8	·0015	72·0	10·8	18·1	Good.....	H	
"	..	1188	"	" ..	"	21	10	46	7	0 45 E.	5-10- 5	" ..	— 0·8	0·8	0·0	0·0	·0012	74·0	10·8	18·08	Poor.....	P	Clouded over.
"	..	1189	"	" ..	"	21	1	10	15	1 40 W.	5-10- 5	" ..	0·0	0·0	— 0·2	— 0·2	·0012	74·0	10·8	18·08	Fair.....	P	Windy.
"	..	1190	"	" ..	"	24	10	40	8	0 30 E.	5-10- 5	" ..	— 1·0	— 1·5	+ 2·0	+ 2·0	·0013	74·0	10·8	18·1	Good at beginning.	P	
"	..	1191	"	" ..	"	28	8	00	8	3 00 E.	5-10- 5	" ..	+ 2·6	+ 2·1	+ 3·8	+ 3·7	·0013	73·5	10·8	18·1	Poor.....	P	
"	..	1192	"	" ..	"	28	10	05	10	1 00 E.	5-10- 5	" ..	— 5·4	— 5·0	+ 3·1	+ 3·1	·0013	73·5	10·8	18·1	Fair.....	P	
"	..	1193	"	" ..	"	28	10	18	10	0 45 E.	6-12- 6	" ..	— 6·0	5·6	+ 3·1	+ 3·1	·0013	73·5	10·8	18·1	"	P	
"	..	1194	"	" ..	"	28	10	29	8	0 35 E.	5-10- 5	" ..	— 5·6	— 5·6	+ 3·1	+ 3·1	·0013	73·5	10·8	18·1	"	P	
"	..	1201	"	" ..	"	28	2	40	10	3 35 W.	4- 4- 4- 4	" ..	8·5	8·5	3·0	3·0	·0013	73·5	10·8	18·1	Good.....	P	
"	..	1202	"	" ..	"	28	2	51	9	3 45 W.	4- 4- 4- 4	" ..	8·5	— 8·5	3·0	3·0	·0013	73·5	10·8	18·1	"	P	
"	..	1203	"	" ..	"	30	2	27	14	3 30 W.	4- 8- 4	" ..	— 5·4	— 5·9	1·5	1·5	·0013	73·5	10·8	18·1	Windy....	P	
"	..	1204	"	" ..	"	30	2	47	25	4 00 W.	4- 8- 4	" ..	— 5·9	6·5	1·5	1·3	·0013	73·5	10·8	18·1	"	P	
					1908.																		
"	..	1206	"	" ..	Jan.	1	12	44	8	1 55 W.	12-12-12-12	" ..	— 8·5	....	— 5·6	...	·0013	72·5	10·8	18·1	Fair.....	P	
"	..	1207	"	" ..	"	1	12	54	8	2 05 W.	4- 8- 4	" ..	— 8·0	....	— 5·6	.....	·0013	72·5	10·8	18·1	Good.....	P	
"	..	1212	"	" ..	"	3	9	39	8	1 00 E.	10-10-10-10	" ..	— 7·0	.....	— 4·4	....	·0013	72·6	10·8	18·1	Fair to poor..	P	
"	..	1213	"	" ..	"	3	9	49	8	0 50 E.	10-10-10-10	" ..	— 7·0	— 7·5	— 4·4	— 4·2	·0013	72·6	10·8	18·1	Fair to poor..	P	
"	..	1219	"	" ..	"	10	12	28	10	2 15 W.	2- 4- 2	" ..	—12·7	.....	—10·5	.....	·0013	72·0	10·8	18·0	Very poor.	P	
"	..	1258	"	" ..	"	22	11	26	13	2 03 W.	1½-1½-1½	" ..	— 8·0	— 9·5	0·2	0·2	·0013	72·5	10·8	18·09	Good.....	H	
"	..	1259	"	" ..	"	22	12	03	11	2 37 W.	1½-1½-1½	" ..	—10·0	10·0	0·2	0·2	·0013	72·5	10·8	18·09	"	H	
"	..	1262	"	" ..	"	23	8	27	10	0 50 E.	1¼-1¼-1¼-1¼	" ..	—11·0	—11·2	— 5·3	— 5·3	·0013	72·5	10·8	18·03	Fair.....	P	
"	..	1263	"	" ..	"	23	8	39	10	0 40 E.	1¼-1¼-1¼-1¼	" ..	—11·2	—10·8	— 5·3	— 5·3	·0013	72·5	10·8	18·03	"	P	
"	..	1265	"	" ..	"	23	9	24	8	0 00	1¼-1¼-1¼-1¼	" ..	—12·6	—12·2	— 5·3	— 5·3	·0013	72·5	10·8	18·03	"	P	
"	..	1266	"	" ..	"	23	9	33	6	0 10 W.	1¼-1¼-1¼-1¼	" ..	—12·2	—13·0	— 5·3	— 5·3	·0013	72·5	10·8	18·03	"	P	
"	..	1267	"	" ..	"	24	6	30	10	2 47 E.	1¼-1¼-1¼-1¼	" ..	—12·7	13·0	— 9·0	9·0	·0013	72·0	10·8	18·0	"	P	
"	..	1268	"	" ..	"	24	6	40	9	2 37 E.	1¼-1¼-1¼-1¼	" ..	—13·0	—13·6	— 9·0	— 9·0	·0013	72·0	10·8	18·0	"	P	
"	..	1269	"	" ..	"	24	6	50	8	2 25 E.	1¼-1¼-1¼-1¼	" ..	—13·7	—14·2	— 9·0	9·0	·0013	72·0	10·8	18·0	"	P	
"	..	1274	"	" ..	"	24	9	27	5	0 10 W.	1¼-1¼-1¼-1¼	" ..	—15·8	—15·6	— 9·0	— 9·0	·0013	72·0	10·8	18·0	Fair to good....	P	
"	..	1275	"	" ..	"	24	9	38	7	0 20 W.	1¼-1¼-1¼-1¼	" ..	—15·6	15·8	— 9·0	— 9·0	·0013	72·0	10·8	18·0	Fair.....	P	
"	..	1277	"	" ..	"	25	10	12	15	1 00 W.	1¼-1¼-1¼-1¼	" ..	— 0·6	— 1·0	— 1·0	— 1·0	·0013	72.5	10·8	18·18	Steady...	P	Partly clouded.
"	..	1278	"	" ..	"	25	10	27	14	1 15 W.	1¼-1¼-1¼-1¼	" ..	— 1·0	— 1·3	— 1·0	— 1·0	·0013	72·5	10·8	18·18	"	P	

ι ORIONIS 1046.

1907. Sept. 14.
G. M. T. 20h 35m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	54·7155	.....	......	....	2	45·2314	....	......	
2	53·3882	·4202	·0179	+20·46	1½	45·1984	·2406	·0019	+ 1·98
1½	53·0779	......	.....	......					

Weighted mean.................... +12·54
V_a............................ +25·82
V_d............................ + ·19
Curvature........... ·28

Radial velocity........... + 38·3

ι ORIONIS 1046 *

1907. Sept. 14.
G. M. T. 20h 35m

Observed by } J. S. PLASKETT.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	54·7422	......	.	.....	2	45·2558		....	....
1	53·4222	·4252	·0229	+26·19	1	45·2060	·2238	·0149	—15·55
1	53·1078	....	....	....					

Weighted mean.................... + 5·32
V_a............................ +25·82
V_d............................ + ·19
Curvature.......... — ·28

Radial velocity.......... .... + 31·0

* Check measurement, the mean +35·0 being used.

ι ORIONIS 1059.

1907. Sept. 18.
G. M. T. 22h 16m

Observed by } W. E. HARPER.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	54·0472	.....	....	....	2	45·2482	·2414	·0027	2·82
1½	53·4304	·4156	·0133	+15·20	1	27·4454	·4300	·0081	+7·02
2	53·1246	.....	....	....	2	27·2618	......	....	.....
2	45·2804	....		....					

Weighted mean.................... + 7·88
V_a............................ +25·77
V_d............................ + ·04
Curvature............. —·28

Radial velocity.......... + 33·4

ι ORIONIS 1069.

1907. Sept. 20.
G. M. T. 21ʰ 19ᵐ

Observed by J. N. Tribble.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	54·0445				1½	45·2719			
2	53·4626	·4496	·0473	+54·06	1½	45·2597	·2614	·0227	+23·70
1	53·1235								

Weighted mean		+41·05
V_a		+25·70
V_d		+ ·12
Curvature	− ·28	
Radial velocity		+66·0

ι ORIONIS 1070.

1907. Sept. 20.
G. M. T. 21ʰ 44ᵐ.

Observed by J. N. Tribble.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	73·0712				2	53·1250			
2	72·9400	·8780	·0132	+19·15	2	45·2785			
2	72·5084				2	45·2603	2554	·0167	17·43
2	54·0546				1	27·4605	·4390	0171	+14·84
1	53·4499	·4320	0297	33·95	2	27·2246			

Weighted mean		+22·80
V_a		+25·70
V_d		+ ·09
Curvature	− ·28	
Radial velocity		+48.3

ι ORIONIS 1076.

1907. Sept. 30.
G. M. T. 21ʰ 18ᵐ.

Observed by J. N. Tribble.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	72·9875				2	45·2743	·2606	·0119	+12·46
2	72·8292	·8126	·0061	−8·86	½	27·4720	·5141	·0176	+15·35
2	72·4221				2	27·2997			
2	54·0271				¼	20·8240	·8585	0264	−21·57
2	53·4095	·3969	·0010	+ 1·14	2	20·5910			
2	53·1135				¼	15·5407	·5873	·0162	−12·60
½	48·3240	·3194	·0075	+ 8·12	2	15·4826			
2	45·2841								

Weighted mean		+ 1·70
V_a		+24·94
V_d		+ ·06
Curvature	− ·28	
Radial velocity		+26.4

ι ORIONIS 1077.

1907. Sept. 30.
G. M. T. 21h 42m

Observed by J. N. Tribble.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	72·9168	.....	.....	.....	2	45·2137	·2737	·0250	+26·17
2	72·7597	·8048	·0139	—20·20	½	27·4230	·5095	·0130	+11·34
1	72·3592	.....	.....	.....	2	27·2350	.....	.....	.....
1	53·9664	.....	.....	.....	⅓	20·7647	·8690	·0159	—13·00
2	53·3351	·3834	·0068	— 7·78	2	20·5212	.....	.....	.....
2	53·0526	.....	.....	.....	1	11·8840	·0204	·0200	+15·00
2	45·2236	.....	.....	.....	2	11·5216	.....	.....	.....

Weighted mean..............		+ 1·32
V_a......................		+ 24·94
V_d......................		·00
Curvature........	— ·28	
Radial velocity..............		+ 26·0

ι ORIONIS 1078.

1907. Sept. 30.
G. M. T. 22h 05m

Observed by J. N. Tribble.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	72·9007	.....	.....	.....	1½	48·2410	·3193	·0074	+ 8·01
2	72·7515	·8145	·0042	— 6·10	2	45·1981	.....	.....	.....
2	72·3363	.....	.....	.....	2	45·1880	·2735	·0248	+25·96
2	53·9450	.....	.....	.....	¼	27·3833	·4923	·0042	— 3·66
2	53·3275	·3997	·0095	+10·95	2	27·2128	.....	.....	.....
2	53·0276	.....	.....	.....	1¼	20·7372	·8558	·0291	—21·82
3	48·6927	.....	.....	.....	2	20·5069	.....	.....	.....

Weighted mean..............		+ 5·05
V_a......................		+ 24·94
V_d......................		·00
Curvature........	— ·28	
Radial velocity..............		+ 29·7

ι ORIONIS 1079.

1907. Sept. 30. Observed by J. N. TRIBBLE.
G. M. T. 20h 28m Measured by W. E. HARPER.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.
2	54·6984	.....	.....	.....	2½	45·2264	·2677	·0190	+19·90
1½	53·3630	3927	0025	+ 2·86	½	27·4335	·5030	·0065	+ 5·67
2	53·0665	.....	.....	.....	2	27·2522	.....	.....	.....
2	45·2423	.....	.....	.....					

Weighted mean .... +12·64
V_a .... +24·94
V_d ... . — ·04
Curvature .... — ·28

Radial velocity .... + 37·3

ι ORIONIS 1097.

1907. Oct. 8. Observed by J. N. TRIBBLE.
G. M. T. 20h 22m Measured by W. E. HARPER.

Wt	Mean of Settings.	Measured Wave Length.	Normal W.L.	Disp^t	Velocity.	Wt.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Disp^t	Velocity.
2	63·3291	4494·788	.....	.....	.....	2	36·1211	4340·995	.....	.....	.....
2	59·5445	4471·384	·676	292	—19·56	½	35·9910	4340·499	·634	·135	— 9·31
2	58·7785	4466·781	.....	.....	.....						

Weighted mean .... —17·51
V_a .... +23·73
V_d .... — ·09
Curvature .... — ·28

Radial velocity .... + 5·8

ι ORIONIS 1108.

1907. Oct. 28 Observed by } W. E. HARPER.
G. M. T. 22h 34m Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.
2	73·1014	.....	.....	.....	2	53·1406	.....	.....	.....
1½	72·9868	·8964	·0310	+45·85	2½	45·3641	·3487	1100	114·84
2	72·5416	.....	.....	.....	2	45·2890	.....	.....	.....
2	54·7815	.....	.....	.....	1	27·5000	·5285	·1066	+92·53
2	53·5220	4914	0891	101·84	2	27·2177	.....	.....	.....

Weighted mean .... +93·15
V_a .... +18·80
V_d .... — ·19
Curvature...... — ·28

Radial velocity .... +111·5

ι ORIONIS 1109.

1907. Oct. 28
G. M. T. $23^h\ 03^m$

Observed by } W. E. Harper.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	73·0950	....	....	....	2	53·1407	....	....	....
1½	73·0040	·9196	·0548	+79·51	2	45·2772	....	....	....
2	72·5270	....	....	....	2	45·3174	·3138	·0751	78·40
2	54·7747	....	....	....	½	27·4892	·5063	·0844	+73·26
½	53·5138	·4758	·0735	84·01	2	27·2294	....	....	....

Weighted mean................		+79·14
V_a....................		+18·80
V_d	− ·22	
Curvature.....	− ·28	
Radial velocity..............		+97·4

ι ORIONIS 1110.

1907. Oct. 29.
G. M. T. $20^h\ 27^m$

Observed by } W. E. HARPER.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
1	73·1635	....	....	....	1	53·5207	·4040	·0017	+ 1·94
½	73·0125	·8592	·0044	− 6·38	1½	53·2281	....	....	....
1	72·5950	....	....	....	2	45·3782	....	....	....
1½	54·8591	....	....	....	1	45·3680	·2634	·0247	+ 25·79

Weighted mean....................		+ 9·81
V_a....................		+ 18·50
V_d..............	− ·04	
Curvature......	− ·28	
Radial velocity...............		+ 28·0

ι ORIONIS 1110.*

1907. Oct. 29.
G. M. T. 20h 27m

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0440	....	....	....	2	53·1060	....	....	....
1½	72·9005	·8677	·0029	+ 4·21	2	45·2563	....	....	....
2	72·4737	....	....	....	2	45·2528	·2701	·0314	32·78
2	54·7368	....	....	....	¼	27·3861	·4288	·0069	+ 5·99
2	53·3997	·4055	·0032	3·66	2	27·2036	....	....	....

Weighted mean....................		+ 14·03
V_a..................		+ 18·50
V_d..........	− ·04	
Curvature....	− ·28	
Radial velocity..............		+ 32·2

*Check measurement.

ι ORIONIS 1111.

1907. Oct. 29.
G. M. T. 20h 56m

Observed by } W. E. Harper.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns.	Velocity.
½	73·0750	....	....	....	2	53·1387	....	....	....
½	72 9210	·8565	·0083	−12·04	2	45·2877	....	....	....
½	72·5071	....	....	....	1½	45·2700	·2559	·0172	+17·96
2	54·7737	....	....	....	½	27·4184	·4319	·0100	+ 8·68
1	53·4664	·4387	·0364	+41·60	2	27·2335	....	....	....

Weighted mean...........		+18·95
V_a.............		+18·50
V_d..........—	·08	
Curvature ..—	·28	
Radial velocity.		+37·1

ι ORIONIS 1112.

1907. Oct. 29.
G. M. T. 21h 26m

Observed by } W. E. Harper.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns.	Velocity.
2	73·1037	....	....	....	2	53·1766	....	....	....
1½	72·9681	·8750	·0102	+14·80	2	45·3253	....	....	....
2	72·5357	....	....	....	1½	45·3078	·2561	·0174	18·16
2	54·8072	....	....	....	¼	27·4795	·4534	·0315	+27·34
2	54·4865	·4217	·0214	24·46	2	27·2727	....	....	....

Weighted mean...........		+20·04
V_a.............		+18·50
V_d..........—	·11	
Curvature ..—	·28	
Radial velocity.		+38·1

ι ORIONIS 1113.

1907. Oct. 29. G. M. T. 21ʰ 58ᵐ

Observed by / Measured by W. E. HARPER.

Wt.	Mean of Settings	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	72·9346	...	...	.	½	54·3201	·4357	·0334	38·17
1½	72·7900	·8651	·0003	+ 0·43	2	53·9954	...	...	...
2	72·3691	.	...	...	2	45·1399	...	...	...
2	54·6304	...	...	...	1½	45·1332	·2669	·0282	+29·44

Weighted mean . ... +18·28
V_a............ ... +18·50
V_d.......... − ·16
Curvature... . − ·28

Radial velocity . . . +36·3

ι ORIONIS 1114.

1907. Oct. 29. G. M. T. 22ʰ 43ᵐ

Observed by / Measured by W. E. HARPER.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	73·0030	..	...	...	2	53·0721	..	...	...
2½	72·8429	·8498	·0150	21·76	2	45·2197	...	...	...
2	72·4376	...	...	...	1½	45·2102	·2641	·0254	+26·51
2	54·7051	...	...	...	½	27·3525	·4179	·0040	— 3·47
1½	53·3520	·3832	·0191	—21·83	2	27·1813	...	...	...

Weighted mean. .... + 8·20
V_a.............. +18·50
V_d . ... − ·19
Curvature.... − ·28

Radial velocity. . . +26·2

ι ORIONIS 1115.

1907. Oct. 30. G. M. T. 18ʰ 42ᵐ

Observed by / Measured by W. E. HARPER.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	54·8325	...	...	...	1½	45·1902	·1071	·1316	137·39
1½	53·3746	·2834	·1189	− 124·47	½	27·3497	·2826	·1393	− 120·91
2	53·2060		...	...	2	27·3137	...	...	...
2	45·3567	.	..						

Weighted mean .... 128·88
V_a... .... −18·18
V_d... . . .. + ·10
Curvature.. .... − ·28

Radial velocity... .... − 110·9

ι ORIONIS 1116.

1907. Oct. 30.
G. M. T. $19^h\ 12^m$

Observed by / Measured by } W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0473	....	....	....	2	45·2756	....	....	....
½	72·8040	7654	·0994	−144·23	½	45·0737	0717	·1670	174·35
1½	72·4867	....	....	....	1	27·2662	·2848	1371	119·00
1½	54·7798	....	....	....	2	27·2279	....	....	....
½	53·2903	·2756	1267	144·82	2	15·3661	....	....	....
1	53·1262	....	....	....	½	15·2765	·3090	1643	−127·17

Weighted mean		−138·09
V	+18·18	
V_d	+ ·08	
Curvature.........	−	·28
Radial velocity	−	120·1

ι ORIONIS 1117.

1907. Oct. 30.
G. M. T. $19^h\ 47^m$

Observed by / Measured by } W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0455	....	....	....	½	53·3016	2867	·1156	132·13
½	72·8085	7728	·0920	−133·49	2	53·1274	....	....	....
1½	72·4810	....	....	....	2	45·2765	....	....	....
2	54·7548	....	....	....	1	45·1154	·1125	·1262	−131·75

Weighted mean..........		−132·28
V_a	+ 18·18	
V_d	+ ·08	
Curvature	−	·28
Radial velocity		−114·3

ι ORIONIS 1118.

1907. Oct. 30.
G. M. T. $20^h\ 26^m$

Observed by / Measured by } W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
1	73·0501	....	....	....	1½	53·1317	....	....	....
¼	72·8222	·7818	·0830	−120·43	2	45·2871	....	....	....
1	72·4855	....	....	....	¾	45·1339	·1204	·1183	125·50
1½	54·7657	....	....	....	½	27·2750	·2715	·1504	−130·55
1	53·3040	2836	·1187	135·67	2	27·2501	....	....	....

Weighted mean..........		−130·07
V_a	+ 18·18	
V_d	−	·03
Curvature	−	·28
Radial velocity		−112·2

ι ORIONIS 1119.

1907. Oct. 30.
G. M. T. 21h 09m

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0338	....	....	....	2	45·2576	....	....	....
½	72·7618	·7385	·1263	−183·26	½	45·0987	·1148	·1239	129·35
1½	72·4674	....	....	....	1	27·2662	·2938	·1281	111·19
1½	54·7416	....	....	....	2	27·2190	....	....	....
½	53·2720	·2700	·1323	151·22	2	15·3557	....	....	....
1	53·1143	....	....	....	½	15·2510	·2939	·1794	−138·86

Weighted mean........		−137·24
V_a............	+18·18	
V_d...		− ·09
Curvature		− ·28
Radial velocity........		−119·4

ι ORIONIS 1120.

1907. Oct. 30.
G. M. T. 21h 49m

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0459	....	....	....	1½	53·1323	....	....	....
½	72·7938	·7568	·1080	−156·71	2	45·2814	....	....	....
1½	72·4831	....	....	....	½	45·1135	·1057	·1330	138·85
2	54·7613	....	....	....	1	27·2586	·2570	·1649	−143·13
½	53·2911	·2709	·1314	150·19	2	27·2454	....	....	....

Weighted mean..		−146·40
V_a............	+18·18	
V_d..		− ·14
Curvature		− ·28
Radial velocity.................		−128·8

ι ORIONIS 1121.

1907. Oct. 31 Observed by J. S. Plaskett.
G. M. T. 18h 47m Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0599	....	....	....	1½	53·1383	......	......	....
½	72·8780	·8300	·0348	− 50·49	2	45·2872	....	....	....
1½	72·4888	....	....	....	½	45·1422	·1288	·1099	114·74
2	54·7706	....	....	....	½	27·2519	·2631	·1588	−137·84
1½	53·3238	2972	·1051	120·13	2	27·2354	....	....	....

Weighted mean.................... −110·58
Vα .... +17·87
Vd .... + ·10
Curvature.............. − ·28

Radial velocity... .... − 92.9

ι ORIONIS 1122.

1907. Oct. 31 Observed by J. S. Plaskett.
G. M. T. 19h 45m Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0509	....	....	....	2	45·2752	....	......	....
2	72·8412	·7988	·0660	− 95·77	2	45·1575	·1559	·0829	86·55
2	72·4911	......	....	....	½	27·2856	·2961	·1258	109·19
2	54·0475	....	....	....	2	27·2360	....	....	....
2	53·3297	·3118	·0905	103·44	½	15·3259	·3527	·1206	− 93·34
2	53·1249	....	....	....	2	15·3718	......	....	....

Weighted mean.... .... − 96·11
Vα .... +17·87
Vd .... + ·02
Curvature... .... − ·28

Radial velocity........... .... − 78·5

ι ORIONIS 1123.

1907. Oct. 31.
G. M. T. 20h 40m

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0181	....	....	....	½	45·1072	·1295	·1092	111·00
½	72·8295	·8219	·0429	−62·25	2	27·2126	....	....	....
2	72·4510	....	....	....	2	20·4696	....	....	....
2	54·7319	....	....	....	½	20·6023	·6525	·1281	104·27
½	53·2796	·2940	·1083	123·79	2	15·3396	....	....	....
2	53·0970	....	....	....	½	15·2841	·3431	·1302	100·77
2	45·2514	....	....	....					

Weighted mean...............		−101·02
V_a..............	+17·87	
V_d.....................		− ·06
Curvature		− ·28
Radial velocity.		83· 5

ι ORIONIS 1124.

1907. Nov. 1.
G. M. T. 18h 35m

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	72·9648	....	....	....	2	45·1927	....	....	....
1	72·7650	·8102	·0546	−79·22	1½	45·0610	·1419	·0968	101·06
2	72·3991	....	....	....	½	20·5629	·6452	·1354	110·21
2	54·6686	....	....	....	2	20·4177	....	....	....
1	53·2242	·2958	·1065	121·73	2	15·2945	....	....	....
2	53·0410	....	....	....	½	15·2807	·3848	·0885	−68·50

Weighted Mean................		−98·31
V_a.	+17·56	
V_d.........	. + ·10	
Curvature..............		− ·28
Radial Velocity		−80· 9

ι ORIONIS 1125.

1907. Nov. 1
G. M. T. 19h 20m

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0315	....	....	......	2	45·2519	......	......	....
2	72·8312	·8100	·0548	−79·51	2	45·1570	·1787	·0600	62·64
2	72·4647	...	...	......	$\frac{1}{4}$	27·2860	3223	·0996	86·45
2	54·7349	......	...	....	2	27·2102	......	......	......
2	53·3142	·3232	·0791	90·41	2	15·3484	......	......	......
2	53·1026	.....	.....	...	$\frac{3}{4}$	15·3090	·3592	·1141	−88·31

Weighted mean..		79·00
V_a....	+17·56	
V_d........	+ ·04	
Curvature....		− ·28
Radial velocity		−61·7

ι ORIONIS 1126.

1907. Nov. 1
G. M. T. 20h

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0472	......	......	......	$\frac{1}{2}$	45·1326	·1349	·1038	108·37
$\frac{1}{2}$	72·8006	7643	·1005	−145·83	2	27·2330	.....	......	......
2	72·4798	......	......	......	$\frac{1}{2}$	27·2995	·3132	1087	94·35
2	54·7497	......	......	......	2	20·5007	......	......	......
$\frac{1}{2}$	53·3095	3015	·1008	115·21	$\frac{1}{2}$	20·6501	6693	·1305	106·22
2	53·1200	....	......	......	2	15·3751	......	......	......
2	45·2714	....	......	......	$\frac{1}{2}$	15·3811	·4046	·0687	· 54·25

Weighted mean..		−104·04
V_a..	+17·56	
V_d..	·00	
Curvature....		·28
Radial velocity..		−96·8

ι ORIONIS 1126.*

1907. Nov. 1.
G. M. T. 20^h

Observed by / Measured by } J. S. Plaskett.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.
2	73·0412				1	45·1225	·1346	·1041	108·47
½	72·8255	·7955	·0693	100·53	½	27·3050	·3300	·0919	86·37
2	72·4711				2	27·2209			
2	54·0318				½	20·6190	·6500	·1306	103·80
1	53·3268	·3270	·0753	86·07	2	20·4890			
2	53·1100				½	15·3200	·3600	·1133	−87·69
2	45·2615				2	15·3615			

Weighted mean		− 95·90
V_a	− 17·56	
V_d	·00	
Curvature		− ·28
Radial velocity		− 88·6

* Check measurement.

ι ORIONIS 1127.

1907. Nov. 1.
G. M. T. $20^h 23^m$

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.
2	73·0357				2	53·1115			
½	72·8528	·8278	·0370	−50·54	2	45·2561			
2	72·4680				½	45·1314	·1491	0896	−93·54
2	54·7377				2	27·2051			
½	53·3468	·3478	.0545	62·29					

Weighted mean		− 68·79
V_a	+ 17·56	
V_d		− ·04
Curvature		− ·28
Radial velocity		− 51·6

ι ORIONIS 1136.

1907. Nov. 11.
G. M. T. 18h 28m

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	72·9926	......	......	....	½	20·7772	·7743	·0063	− 5·13
½	72·8419	·8584	·0064	− 9·23	2	20·5231	....	....	....
2	72·4308	....	....	....	1	15·5042	·4979	0246	+ 19·04
2	45·2621	....	....	....	2	15·4050	....	....	......
½	45·2245	·2355	·0032	− 3·34	1½	11·8618	·8603	·0089	+ 6·67
2	27·2420	....	....	......	2	11.5086	....	....	....
½	27·4060	·4106	·0113	− 9·81					

Weighted mean.................. + 3·37
Va.................... + 14·17
Vd .... + ·07
Curvature...... − ·28

Radial velocity................ + 17.3

ι ORIONIS 1136*

1907. Nov. 11
G. M. T. 18h 28m

Observed by } W. E. Harper.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	72·9950	....	......	....	1	20·7660	·7556	·0250	− 20·35
1	72·8435	·8575	·0073	− 10·59	2	20·5308	....	......	....
2	72·4333	....	....	....	1	15·4940	·4818	·0085	− 6·58
2	45·2652	......	....	....	2	15·4108	....	....	....
½	45·2622	·2705	·0317	+ 34·50	1½	11·8659	·8604	·0090	− 6·74
1	27·4337	·4327	·0108	+ 9·37	2	11·5120	....	....	....
2	27·2477	......	....	....					

Weighted mean .... + 2·06
Va .... + 14·17
Vd .... + ·07
Curvature...... − ·28

Radial Velocity................ + 16·0

*Check measurement.

ι ORIONIS 1137.

1907. Nov. 11.
G. M. T. 19h 07m.

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	72·9998				2	45·2740			
½	72·8521	·8617	·0031	− 4·50	½	45·2388	·2384	·0003	− 0·31
2	72·4362				2	27·2602			
2	54·7390				½	27·4570	·4436	·0217	+18·84
1	53·4180	·4242	·0219	+25·03	2	20·5420			
2	53·1050				½	20·8277	·8060	·0254	+20·68

Weighted mean	−14·13
V_a	−14·17
V_d	+ ·01
Curvature... − ·28	
Radial velocity	+28·0

ι ORIONIS 1141.

1907. Nov. 15.
G. M. T. 18h 02m

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	72·9746				2	53·0929			
½	72·8089	·8425	·0223	−32·36	2	45·2578			
2	72·4154				½	45·2411	·2569	·0182	+19·00
2	54·7246				2	27·2555			
½	53·4097	·4286	·0263	+30·06	½	27·4851	·4765	·0546	+48·42

Weighted mean	+16·28
V_a	+12·63
V_d	+ ·09
Curvature... − ·28	
Radial velocity	+28·7

ι ORIONIS 1142.

1907. Nov. 15.
G. M. T. 18^h 19^m

Observed by W. E. HARPER.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}.	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}.	Velocity.
2	72·9845				2	53·1006			
½	72·8334	·8571	·0077	−11·17	2	45·2669			
2	72·4253				½	45·2613	·2680	·0293	+30·59
2	54·7302				2	27·2628			
½	53·4121	·4236	·0213	+24·34	½	27·4575	·4415	·0196	+17·01

Weighted mean	+15·19
V_a	+12·63
V_d	+ ·06
Curvature	— ·28
Radial Velocity	+27·6

ι ORIONIS 1143.

1907. Nov. 15.
G. M. T. 18^h 36^m

Observed by W. E. HARPER.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}.	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}.	Velocity.
2	54·7535				2	27·2942			
½	53·4373	·4248	·0225	+25·72	½	27·5026	·4554	·0335	+29·07
2	53·1247				2	20·5812			
2	45·2965				½	20·8614	·8008	·0202	+16·44
½	45·2878	·2649	·0262	+27·35					

Weighted mean	+24·64
V_a	+12·63
V_d	+ ·03
Curvature	— ·28
Radial velocity	+37·0

ιORIONIS 1147.

1907. Nov. 16.
G. M. T. 17ʰ 20ᵐ

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	73·0063	....	....	....	2	45·3063	....	....	....
1	72·8944	·8971	·0323	+46·87	1	45·2902	·2575	·0188	19·63
2	72·4452	....	....	....	2	27·3171	....	....	....
2	54·7582	....	....	....	½	27·5420	·4719	·0500	43·40
½	53·4526	·4317	·0294	33·60	2	20·5989	....	....	....
2	53·1340	....	....	....	½	20·8887	·8095	·0289	+23·52

Weighted mean........		+33·36
V_a........		+12·25
V_d........		+ ·12
Curvature......	− ·28	
Radial velocity........		+45·4

ιORIONIS 1148.

1907. Nov. 16.
G. M. T. 17ʰ 40ᵐ

Observed by J. S. Plaskett
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	72·9794	....	....	....	2	45·2697	....	....	....
1	72·8322	·8628	·0020	— 2·90	½	45·2697	·2736	·0349	+36·44
2	72·4137	....	....	....	2	27·2717	....	....	....
2	54·7290	....	....	....	½	27·4928	·4680	·0461	+40·01
1	53·4398	4495	·0472	+53·95	2	20·5574	....	....	....
2	53·1032	....	....	....	½	20·8315	·7946	0140	+11·40

Weighted mean........		+27·13
V_a........		+12·25
V_d........		+ ·11
Curvature......	— ·28	
Radial velocity........		+39·2

ι ORIONIS 1161.

1907. Nov. 28.
G. M. T. 21ʰ 08ᵐ

Observed by J. S. PLASKETT.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	54·7524	....	....	....	½	27·2370	·2785	·1434	124·46
½	53·2823	·2737	·1286	− 146·99	2	27·2051	....	....	....
2	53·1204	....	....	....	2	15·3372	....	....	....
2	45·2622	....	....	....	¼	15·2620	·3234	·1499	− 116·02
¼	45·0952	·1066	·1321	137·91					

Weighted mean........		− 132·80
V_a	+ 6·80	
V_d	−	·22
Curvature.......... ..	−	·28
Radial velocity.......	−	126·5

ι ORIONIS 1161.*

1907. Nov. 28.
G. M. T. 21ʰ 08ᵐ

Observed by, Measured by } J. S. PLASKETT.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	73·0507	....	....	....	¾	45·1247	·1427	·0960	100·20
½	72·8140	·7720	0928	− 134·65	2	43·5126	....	....	....
2	72·4924	....	....	....	½	27·2550	·2990	·1229	106·67
1	54 0324	....	....	....	2	27·2021	....	....	....
1	53·3012	·2977	·1046	115·26	2	15·3322	....	....	....
2	53·1158	....	....	....	½	15·2784	·3454	·1279	− 99·03
2	45·2562	....	....	....					

Weighted mean........	−	110·17
V_a	+ 6·80	
V_d	−	·22
Curvature	−	·28
Radial velocity....	−	103·9

* Check measurement.

ι ORIONIS 1161.*

1907. Nov. 28.
G. M. T. $21^h\ 08^m$.

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	72·9617	...	...	...	3	45·1636	...	...	...
½	72·7048	·7525	·1123	−162·85	1	45·0212	·1312	·1075	112·23
1½	72·3985	...	...	...	2	27·1065	...	...	...
2	53·9388	...	...	...	½	27·1502	·2900	·1319	114·49
½	53·1973	·2877	·1146	130·99	2	15·2349	...	...	...
2	53·0216	...	...	...	½	15·1660	·3297	·1636	−126·63

Weighted mean....		126·57
V_a	+6·80	
V_d...		− ·22
Curvature....		− ·28
Radial velocity.............		−120·3

* Second check measurement.

ι ORIONIS 1162.

1907. Nov. 28.
G. M. T. $21^h\ 30^m$

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	45·3964	...	...	...	2	27·3308	...	...	...
½	45·2433	·1208	·1179	−123·08	½	15·3655	·3116	·1617	125·16
2	44·3798	...	...	...	2	15·4527	...	...	...
1	27·3032	·2190	·2029	176·12					

Weighted mean		−150·12
V	+6.80	
V_d		− ·23
Curvature....		− ·28
Radial velocity....		−143·8

ι ORIONIS 1162.*

1907, Nov. 28.
G. M. T. 21ʰ 30ᵐ

Observed by | J. S. Plaskett.
Measured by |

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	73·0700	...	...	...	2	43·5136	...	...	...
½	72·8474	·7874	0774	—112·32	¼	27·1864	·2440	·1779	154·40
2	72·5033	...	...	...	2	27·1888	...	...	...
2	45·2536	...		...	½	15·2524	3364	·1369	—106 00
½	45·1152	·1362	1025	106 98	2	15·3137	...	...	...

Weighted mean....		— 115·00
V_a	+ 6·80	
V_d		— ·23
Curvature......		— ·28
Radial velocity.....		— 108·7

* Check measurement.

ι ORIONIS 1162.*

1907, Nov. 28.
G. M. T. 21ʰ 30ᵐ

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	73·1068	...	...	...		27·2115	·2335	·1884	163·53
½	72·8884	·7913	·0735	—106 65	2	27·2246	...	...	...
2	72·5422	...	...	...	2	15·3453	...	...	...
2	45·2915	...	...	...	½	15·2825	·3358	·1375	—106·42
1½	45·1452	1273	·1114	116·30					

Weighted mean...		— 120·91
V_a	+ 6·80	
V_d		— ·23
Curvature		— ·28
Radial velocity		— 114·6

*Second check measurement.

ι ORIONIS 1166.

1907 Nov. 29.
G. M. T. 21h 41m

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0522	....	....	....	1	45·1060	·1374	·1013	105·76
½	72·8498	·8084	·0564	— 81·84	2	44·2251	....	....	....
2	72·4845	....	....	....	½	27·2503	·3198	·1021	88·62
2	72·7322	....	....	....	2	27·1770	....	....	....
1	53·3124	·3225	·0798	91·21	½	15·2792	·3780	·0953	– 73·76
2	53·1018	....	....	....	2	15·2998	....	....	.. .
2	45·2427	....	....	....					

Weighted mean........		–91·16
V_a	+6·43	
V_d		– ·25
Curvature.........		- ·28
Radial velocity.......		– 85·3

ι ORIONIS 1167.

1907 Nov. 29.
G. M. T. 21h 58m

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0612	....	....	....	½	45·1125	·1189	·1198	125·07
½	72·8198	·7670	·0978	-141·91	2	44·2489	....	....	....
2	72·4996	....	....	....	½	27·2197	·2592	·1627	141·22
2	54·7544	....	....	....	2	27·2071	....	....	....
¼	53·2647	·2541	·1482	169·39	¼	15·2647	·3353	·1380	–106·81
2	53·1224	....	....	....	2	15·3281	....	....	....
2	45·2680	....	....	....					

Weighted mean..........		–136·57
V_a	+ 6·43	
V_d		– ·28
Curvature...........		– ·28
Radial velocity..........		– 130·7

ι ORIONIS 1167*

1907. Nov. 29.
G. M. T. $21^h\ 58^m$

Observed by / Measured by } W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	73·0566	...	...	...	2	53·1160	...	...	...
½	72·8090	·7618	·1030	− 149·45	2	45·2635	...	...	...
2	72·4932	...	...	...	¼	45·1252	·1352	·1035	108·05
2	54·7458	...	...	...	¼	27·2835	·3323	·0896	− 77·77
¼	53·3060	3020	·1003	114·64	2	27·2978	...	...	...

Weighted mean		·119·86
V_a	− 6·43	
V_d		− ·28
Curvature....		·28
Radial velocity		−114·0

*Check measurement: −120 accepted result.

ι ORIONIS 1168.

1907. Dec. 3.
G. M. T. $15^h\ 25^m$

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	72·9936	...	...	...	½	45·1582	·1973	·0414	43·22
1	72·8201	·8342	·0306	44·40	2	44·2191	...	...	...
2	72·4358	...	...	...	¼	27·3302	·3808	·0411	35·67
2	54·7115	...	...	...	2	27·1959	...	...	...
¼	53·3080	·3393	·0630	72·01	½	15·3780	·4346	·0387	− 29·95
2	53·0806	...	...	...	2	15·3420	...	...	...
2	45·2346	...	...	...					

Weighted mean..		− 43·16
V_a..........	+ 4·75	
V_d....... .	+ ·19	
Curvature....		− ·28
Radial velocity		− 38·5

ι ORIONIS 1169.

1907. Dec. 3.
G. M. T. 15ʰ 36ᵐ

Observed by J. S. PLASKETT.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	73·0222	......	......	......	½	45·2387	·2367	·0020	2·09
½	72·8747	·8617	0031	– 4·50	2	45·2756	......	......	......
2	72·4596	......	......	......	¼	27·4303	·4413	·0194	– 16·84
2	54·7477	......	......	......	2	27·2355	......	......	......
½	54·3728	·3645	·0378	– 43·20	1	15·4306	4507	·0226	– 17·49
2	53·1207	......	......	......	2	15·3785	......	......	......

Weighted mean......		– 13·88
V_a	+ 4·75	
V_d	+ ·17	
Curvature......		– ·28
Radial velocity		– 9·2

ι ORIONIS 1170.

1907. Dec. 3.
G. M. T. 15ʰ 48ᵐ

Observed by J. S. PLASKETT.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	73·0263	......	......	......	2	44·2491	......	......	......
½	72·8605	·8445	0203	– 29·46	¼	27·3948	·4114	0105	– 9·11
2	72·4597	......	......	......	2	27·2299	......	......	......
2	54·7401	......	......	......	½	20·6982	·7165	·0641	– 52·18
½	53·3781	·3798	0225	– 25·72	2	20·5017	......	......	......
2	53·1106	......	......	......	½	11·8440	·8785	·0266	+ 91·92
2	45·2685	......	......	......	2	11·4720	......	......	......
¼	45·1927	·1981	0406	– 42·39					

Weighted mean....................		– 30·64
V_a	+ 4·75	
V_d	+ ·16	
Curvature..............		– ·28
Radial velocity................		– 26·0

ι ORIONIS 1178.

1907. Dec. 4.
G. M. T. 17h 27m

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0413	....	....	....	2	53·1177	....	....	....
1½	72·8768	·8452	·0196	−28·44	½	45·2436	·2452	·0065	+ 6·79
2	72·4767	....	....	....	2	45·2720	....	....	....
2	54·7452	....	....	....	½	27·3877	·4013	·0206	−17·88
1	53·3915	·3862	.0161	−18·42	2	27·2340	....	....	....

Weighted mean..............		− 19·03
V_a	+ 4·33	
V_d	+ ·02	
Curvature		− ·28
Radial velocity..............		− 15·0

ι ORIONIS 1188.

1907. Dec. 21.
G. M. T. 15h 46m

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0552	....	....	....	½	53·5004	·4715	.0692	79·13
½	72·9681	92·26	·0578	+83·88	2	53·1390	....	....	....
2	72·4906	....	....	....	2	45·2915	....	....	....
2	54·0604	....	....	....	½	45·3025	·2845	·0458	+47·80

Weighted mean...		+ 74·76
V_a	− 3·54	
V_d		+ ·02
Curvature	− ·28	
Radial velocity............ .		+ 71·0

ι ORIONIS 1189.

1907. Dec. 21.
G. M. T. $18^h\ 10^m$

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	73·0774	....	....	....	2	44·7824	....	....	....
1	72·9963	·9273	·0625	+ 90·70	1	44·8130	·3042	·0655	68·36
2	72·5164	....	....	....	½	27·0224	·5263	·1044	90·61
2	53·5540	....	....	....	2	26·7427	....	....	....
1	52·9977	·4757	·0734	83·94	½	14·6664	·6323	·1593	+123·35
2	52·6326	....	....	....	2	14·4327	....	....	....

Weighted mean .... +83·28
V_a .... −3·57
V_d .... − ·13
Curvature ..... − ·28

Radial velocity .... +79·2

ι ORIONIS 1190.

1907. Dec. 24.
G. M. T. $15^h\ 40^m$

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	73·0062	....	....	....	1	45·2830	·3370	·0983	102·60
1	72·9266	·9285	·0637	+ 92·44	2	45·2192	....	....	....
2	72·4464	....	....	....	½	27·4368	·5205	·0989	85·84
2	53·9920	....	....	....	2	27·1620	....	....	....
½	53·4803	·5153	·1130	129·22	1	15·5273	·6330	·1597	+123·66
2	53·0787	....	....	....	2	15·2920	....	....	....

Weighted mean .... +106·58
V_a .... −4·88
V_d .... + ·04
Curvature ..... − ·28

Radial velocity .... +101·5

ι ORIONIS 1191.

1907. Dec. 28
G. M. T. 13h

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0603	....	....	....	2	30·8396	....	....	....
½	72·8436	·7946	·0702	−101·87	½	28·5014	·5352	·1183	103·93
2	72·4910	....	....	....	½	27·2971	·3361	·0942	81·76
2	54·0477	....	....	....	2	27·2070	....	....	....
½	53·3462	·3307	·0716	81·88	½	20·5932	·6462	·1344	109·37
2	53·1256	....	....	....	2	20·4670	....	....	....
2	45·2714	....	....	....	½	15·3137	·3846	·0887	− 68·68
½	45·1374	·1400	·0987	103·01	2	15·3287	....	....	....
2	43·5297	....	....	....					

Weighted mean		−97·57
V_a		− 6·64
V_d	+ 0·22	
Curvature		− 0·28
Radial velocity		−104·3

ι ORIONIS 1192.

1907. Dec. 28
G. M. T. 15h 05m

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
3	73·0167	....	....	....	3	45·2280	....	....	....
1	72·8150	·8085	0563	− 81·70	1	45·0738	·1195	·1192	124·41
3	72·4507	....	....	....	½	27·2082	·3492	·0727	63·10
2	54·0001	....	....	....	2	27·1771	....	....	....
1	53·2563	·2845	·1178	134·72	½	20·5304	·6080	·1726	−140·46
2	53·0843	....	....	....	2	20·4424	....	....	....

Weighted mean		−110·65
V_a		− 6·68
V_d	+ ·07	
Curvature		− ·28
Radial velocity		−117·5

ι ORIONIS 1193.

1907. Dec. 28. G. M. T. 15^h 18^m

Observed by, Measured by } J. S. Plaskett.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	73·0757				2	30·8342			
1	72·8526	·7862	·0786	−114·06	½	28·4722	·5167	·1368	120·19
2	72·1524				½	27·2457	·2937	·1282	111·26
2	54·0462				2	27·1976			
½	53·3165	·3020	·1003	114·70	¼	20·5587	·6165	·1641	133·54
2	53·1258				2	20·4620			
2	45·2652				¼	15·2884	·3634	·1100	85·17
1	45·1469	·1555	·0832	86·84	2	15·3227			

Weighted mean	−107·16
V_a	− 6·68
V_d	+ ·05
Curvature	·28
Radial velocity	− 114·1

ι ORIONIS 1194.

1907. Dec. 28. G. M. T. 15^h 29^m

Observed by, Measured by } J. S. Plaskett.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	73·0740				1	45·1340	·1275	·1112	116·06
1	72·8390	·7765	·0883	−128·14	½	27·2787	·2980	·1239	107·53
2	72·5068				2	27·2266			
2	54·0544				¼	20·6380	·6680	·1126	91·63
1	53·3222	·2966	·1057	120·88	2	20·4900			
2	53·1377				½	15·2950	·3390	·1342	−103·99
2	45·2804				2	15·3542			

Weighted mean	116·18
V_a	− 6·68
V_d	+ ·04
Curvature	− ·28
Radial velocity	−123·1

ι ORIONIS 1201.

1907. Dec. 28
G. M. T. 19h 40m

Observed by / Measured by } J. S. PLASKETT.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.
2	73·0644	......	......	......	½	45·1351	·1465	·0922	96·23
¼	72·8316	·7774	·0874	—126·83	½	27·2532	·2875	·1344	116·64
2	72·4984	......	......	......	2	27·2120	......	......	......
2	54·0412	......	......	......	¼	20·6014	·6402	·1404	114·25
½	53·3302	·3202	·0829	93·89	2	20·4812	......	......	......
2	53·1210	......	......	......	½	15·2994	·3530	·1203	93·15
2	45·2625	......	......	......	2	15·3450	......	......	......

Weighted mean	—106·16
V_a....	— 6·76
V_d	— ·25
Curvature.........	— ·28
Radial velocity......	— 113·4

ι ORIONIS 1202.

1907. Dec. 28.
G. M. T. 19h 51m

Observed by / Measured by } J. S. PLASKETT.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.
2	73·0405	......	......	......	½	45·1005	·1280	·1107	115·53
¼	72·8150	·7850	·0798	—115·81	¼	27·2350	·2990	·1229	106·66
2	72·4750	......	......	......	2	27·1821	......	......	......
2	54·0202	......	......	......	¼	20·5322	6055	·1751	142·50
½	53·2996	·3081	·0942	107·73	2	20·4462	......	......	......
2	53·1038	......	......	......	¼	15·2402	·3285	·1448	—112·12
2	45·2462	......	......	......	2	15·3098	......	......	......

Weighted Mean..	—115·56
V_a................	— 6·76
V_d............. .	— ·25
Curvature...	— ·28
Radial velocity.........	— 122·8

ι ORIONIS 1203.

1907. Dec. 30.
G. M. T. 19ʰ 27ᵐ

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	73·0160	....	....	....	½	45·1414	1804	0583	60·86
1½	72·8514	·8439	0209	−30·32	½	27·3349	4005	0214	18·58
2	72·4553	....	....	....	2	27·1808	....	....	....
2	54·7175	....	....	....	2	20·4458	....	....	....
1	53·3483	3740	·0283	32·35	¼	15·3175	·4005	·0728	56·34
2	53·0861	....	....	....	2	15·3156	....	....	....
2	45·2348	....	....	....					

Weighted mean..............	−	35·10
V_a	−	7·65
V_d	−	·25
Curvature..........................	−	·28
Radial velocity	−	43·1

ι ORIONIS 1204.

1907. Dec. 30.
G. M. T. 19ʰ 47ᵐ

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	73·0368	....	....	....	½	45·1771	·2151	·0236	24·64
1½	72·8619	·8351	0297	−43·09	¼	27·2953	3690	·0529	45·92
2	72·4699	....	....	....	2	27·1727	....	....	....
2	54·7217	....	....	....	2	20·4311	....	....	....
1	53·3351	·3582	·0441	50·41	1	15·3263	·4287	·0446	−34·52
2	53·0885	....	....	....	2	15·2962	....	....	....
2	45·2356	....	....	....					

Weighted mean..............		40·97
V_a	−	7·65
V_d	−	·28
Curvature..........................	−	·28
Radial velocity.....................	−	49·2

ι ORIONIS 1206.

1908. Jan. 1.
G. M. T. $17^h\ 44^m$

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.
2	73·0104	....	....	....	½	45·1876	·2382	·0005	0.52
1½	72·8445	·8441	·0207	30·04	½	27·3378	·4015	·0204	38·11
2	72·4450	....	....	....	2	27·1829	....	....	....
2	54·7112	....	....	....	2	20·4529	....	....	....
1	53·3621	·3993	·0030	3·43	¼	15·3684	·4424	·0309	−54·82
2	53·0705	....	....	....	2	15·3246	....	....	....
2	45·2230	....	....	....					

Weighted mean	− 21·73
V_a	− 8·49
V_d	− ·15
Curvature	− ·28
Radial velocity	− 30·6

ι ORIONIS 1207.

1908. Jan. 1.
G. M. T. $17^h\ 54^m$

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean. of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.
2	73·0202	....	....	....	2	45·2500	....	....	....
2	72·8691	·8559	·0089	−12·92	½	45·1955	·2191	·0196	−20·46
2	72·4644	....	....	....	¼	27·3682	·4119	·0100	− 8·68
2	54·7302	....	....	....	¼	15·4206	·4753	·0020	+ 1·54
1½	53·3729	·3835	·0188	−21·48	2	15·3439	....	....	....
2	53·1016	....	....	....					

Weighted mean	− 15·57
V_a	8·49
V_d	− ·16
Curvature	− ·28
Radial velocity	− 24·5

ι ORIONIS 1212.

1908. Jan. 3.
G. M. T. 14ʰ 39ᵐ

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	72·9869				2	53·0591			
2	72·8550	·8784	·0136	+19·73	2	45·2082			
2	72·4197				1	45·1630	·2284	·0103	-10·76
2	54·6914				½	27·3483	·4135	·0084	- 7·29
1	53·3595	·4104	·0081	+ 9·26	2	27·1631			

Weighted mean .... + 7·62
V_a .... - 9·33
V_d .... + ·09
Curvature .... - ·28

Radial velocity .... 1·9

ι ORIONIS 1213.

1908. Jan. 3.
G. M. T. 14ʰ 49ᵐ

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	73·0457				2	45·2436			
2	72·9059	·8697	·0049	+ 7·11	1	45·2000	·2300	·0087	- 9·08
2	72·4819				½	27·3521	·4121	·0098	- 8·67
2	54·7352				2	27·1863			
1½	53·3953	·4071	·0048	+ 5·49	¼	20·6785	·7463	·0343	-27·96
2	53·0990				2	20·4519			

Weighted mean .... + 0·39
V_a .... -9·33
V_d .... + ·08
Curvature .... - ·28

Radial velocity .... - 9·1

ι ORIONIS 1219.

1908. Jan. 10
G. M. T. $17^h\ 28^m$

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	72·9958	....	....	....	¼	48·3716	·3676	·0669	72·23
½	72·8962	·9095	·0447	+64·87	½	45·2916	·2850	·0463	48·32
2	72·4327	....	....	....	2	45·2802	....	....	....
1	54·0287	....	....	....	¼	27·4973	·4660	·0441	38·27
½	53·4557	·4537	·0514	58·78	2	27·2786	....	....	....
2	53·1154	....	....	....	½	20·8537	·8140	·0334	+27·18
2	48·7726	....	....	....	2	20·5617	....	....	....

Weighted mean....................		+49·13
V_a	− 12·31	
V_d	− 0·17	
Curvature......	− 0·28	
Radial velocity......		+ 36·4

ι ORIONIS 1258.

1908. Jan. 22.
G. M. T. $16^h\ 26^m$

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	73·0539	....	....	....	1½	45·3004	·3315	·0928	96·88
2	72·9523	·9089	·0441	+ 63·99	2	45·2425	....	....	....
2	72·4852	....	....	....	½	27·4588	·4990	·0771	66·92
2	54·7336	....	....	....	2	27·2063	....	....	....
1½	53·4666	·4806	·0783	89·50	¼	15·5545	·6098	·1365	+105·65
2	53·0964	....	....	....	2	15·3428	....	....	....

Weighted mean....................		+81·30
V_a..............	− 16·88	
V_d............	− ·16	
Curvature........	− ·28	
Radial velocity......		+ 64·0

ι ORIONIS 1258.*

1908. Jan. 22.
G. M. T. 16^h 26^m

Observed by } W. E. Harper.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.
2	73·0780				1½	45·3493	·3512	1125	117·45
1	73·0077	·9400	·0752	+109·11	2	45·2717			
1	72·5112				1	27·5468	·5585	·1366	118·57
1½	54·0495				2	27·2328			
1	53·4869	·4687	·0664	75·90	½	15·6297	·6577	·1844	+142·72
2	53·1290				2	15·3700			

Weighted mean........	+110·22
V_a	−16·88
V_d	− ·16
Curvature ...	− ·28
Radial velocity... ..	+ 92·9

* Check measurement.

ι ORIONIS 1259.

1908. Jan. 22.
G. M. T. 17^h 03^m

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.
2	73·0069				2	45·2287			
1	72·9156	·9191	·0543	+78·79	½	27·4702	·5323	·1104	95·83
2	72·4385				2	27·1842			
2	54·7122				½	15·5499	·6241	·1508	+116·72
1	53·4594	4898	·0875	100·00	2	15·3242			
2	53·0814								
1	45·2886	3335	·0948	98·97					

Weighted mean...........	+96·01
V_a.............	−16·88
V_d.	− ·19
Curvature.	− ·28
Radial velocity..........	+78·7

ι ORIONIS 1259*

1908. Jan. 22.
G. M. T. 17^h 03^m

Observed by, Measured by } W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0603	....	....	....	2	45·2795	....	....	....
1½	72·9506	·9003	·0355	+51·52	1	27·5680	·5779	·1560	135·59
2	72·4945	....	....	....	2	27·2365	....	....	....
3	57·8563	....	....	....	½	20·8613	·8740	·0934	76·00
2	54·0521	....	....	....	2	20·5072	....	....	....
1	53·5196	·4976	·0953	108·98	1	15·6030	·6270	·1537	+119·00
2	53·1335	....	....	....	2	15·3742	....	....	....
1	45·3277	·3197	·0810	84·53					

Weighted mean .... +93·86
V_a .... −16·88
V_d .... − ·19
Curvature... − ·28

Radial velocity .... +76·5

* Check measurement.

ι ORIONIS 1262.

1908. Jan. 23.
G. M. T. 13^h 27^m

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0116	....	....	....	2	45·3203	·3329	·0942	98·34
2	72·9588	·9576	·0928	+134·65	2	45·2410	....	....	....
2	72·4416	....	....	....	1	27·5200	·5610	·1391	120·74
2	54·7243	....	....	....	2	27·2055	....	....	....
2	53·4805	·5005	·0982	112·24	¼	15·6007	·6492	·1759	+136·14
2	53·0912	....	....	....	2	15·3500	....	....	....

Weighted Mean............ +116·58
V_a .... −17·31
V_d .... + ·09
Curvature... − ·28

Radial velocity... ..... +99·1

ι ORIONIS 1262*

1908. Jan. 23.
G. M. T. $13^h\ 27^m$

Observed by } J. S. PLASKETT.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0200	....	....	....	1	45·3416	·3630	·1243	129·73
½	72·9583	·9480	·0832	+ 120·74	2	45·2522	.....	....	..
1	72·4585	....	.. ..	.. ..	½	27·5438	·5730	·1513	131·31
2	54·7346	... ..	..	.....	2	27·2172	....	... ...	... ...
1	53·4966	·5066	·1043	119·27	½	20·9045	·9375	·1569	+ 127·68
2	53·1005	....		.... .	2	20·4866	.... . .	. ...	. . ...

Weighted mean .... + 125·39
V_a........ . .... − 17·31
V_d...... .... + ·09
Curvature . .. − ·28

Radial velocity. .... + 107·9

* Check measurement.

ι ORIONIS 1263.

1908 Jan. 23.
G. M. T. $13^h\ 39^m$

Observed by J. S. PLASKETT.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0395	. ....	... .	....	2	45·3299	·3515	·1128	117·76
1	72·9916	·9620	·0972	+ 141·04	2	45·2520	.. ..	...	....
2	72·4744	....	.. ...	....	1	27·4624	·5060	·0841	73·00
2	54·7377	....	.... ..	....	2	27·2027	....	....	....
2	53·4958	·4998	·0975	111·44	¼	15·5665	·6235	·1502	+ 116·25
2	53·1087	....	. ....	....	2	15·3411	... ..	. ....	. . ....

Weighted mean .... + 112·24
V_a............... − 17·31
V_d. .... + ·06
Curvature. ...... − ·28

Radial velocity.......... .... + 94·7

ι ORIONIS 1263.*

1908. Jan. 23.
G. M. T. 13h 39m

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0670	....	....	....	2	45·2795	....	....	....
1	73·0282	·9718	·1070	+155·26	½	27·4987	5147	·0928	80·55
½	72·4990	....	....	....	2	27·2300	....	....	....
½	66·3447	3016	·1137	151·45	1	20·9045	·9310	·1504	122·42
2	54·7649	....	....	....	2	20·4930	....	....	....
1	53·5430	·5232	·1209	138·25	1	15·6063	·6383	·1650	+127·71
1½	53·1311	....	....	....	2	15·3665	....	....	....
1	45·3650	3591	1204	125·70					

Weighted mean.........	+130·90
V_a	17·31
V_d.....................	+ ·06
Curvature	− ·28
Radial velocity.	+ 113·4

* Check measurement.

ι ORIONIS 1265.

1908. Jan. 23.
G. M. T. 14h 24m

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
1½	73·0823	....	....	....	1	53·1506	....	....	....
1	73·0381	9658	·1010	+146·55	1½	45·3950	·3776	·1389	145 01
1	72·5160	....	....	....	2	45·2910	....	....	....
2	57·8679	....	....	....	1	27·5965	·5969	·1750	+151·90
1	54 0628	....	....	....	1	27·2462	....	....	....
1½	53·5166	·4795	·0772	88·24					

Weighted mean	+129·66
V_a.............	−17·31
V_d	·00
Curvature.........	− 28
Radial velocity..........	+112·0

ι ORIONIS 1266.

1908. Jan. 23.
G. M. T. 14h 33m

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0153	...	...	...	1	45·3003	3224	0837	87·38
1½	72·9310	·9247	0599	+ 86·91	2	45·2515	...	...	...
2	72·4559	...	...	...	½	27·4910	·5176	0957	83·07
2	54·7312	...	...	...	2	27·2200	...	...	...
1	53·4792	·4904	·0881	100·70	½	15·5689	6022	·1289	+ 99·77
2	53·0092	...	...	...	2	15·3653	...	...	...

Weighted mean....		91·08
V_a	– 17·31	
V_d	01	
Curvature ...	·28	
Radial velocity.....		73·5

ι ORIONIS 1266.*

1908. Jan. 23.
G. M. T. 14h 33m

Observed by J. S. Plaskett.
Measured by J. S. Plaskett.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0234	...	...	...	2	45·2602	...	...	...
1	72·9542	·9400	0752	+109·13	¼	27·5061	5215	·0996	86·44
2	72·4622	...	...	...	2	27·2310	...	...	...
1	54·0274	...	...	...	¼	20·9098	·9195	1389	113·04
1	53·4954	4994	0971	111·05	2	20·5012	...	...	...
2	53·1065	...	...	...	¼	15·5955	6190	·1457	+112·82
	45·3192	3325	0938	97·90	2	15·3749	...	...	...

Weighted mean................		+103·76
V_a	– 17·31	
V_d	– ·01	
Curvature....	– ·28	
Radial velocity..........		86·2

*Check measurement.

ι ORIONIS 1267.

1908. Jan. 24.
G. M. T. 11ʰ 40ᵐ

Observed by } J. S. PLASKETT.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	73·0014	......	......	......	2	45·2700		......	....
¼	72·9668	·9740	·1092	+158·47	½	27·5734	5410	1191	103·37
2	72·4391	......	......	......	2	27·2696	...	...	....
2	54·0260	......	......	......	¼	20·9524	9220	·1414	115·07
½	53·5284	·5306	·1273	145·57	1½	20·5518	......	......	......
2	53·1103	......	......	......	¼	15·6824	6404	1671	+129·38
½	45·3414	3450	·1063	110·94	2	15·4418	......	......	......

Weighted mean .... +124·74
V_a......... —17·50
V_d.................+ ·21
Curvature ..— ·28

Radial velocity. ..... +107·2

ι ORIONIS 1268.

1908. Jan. 24.
G. M. T. 11ʰ 40ᵐ

Observed by J. S. PLASKETT.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispᵗ in revⁿˢ	Velocity.
2	72·9930	......	......	......	1½	45·3092	3365	·0978	102·10
1	72·9194	·9363	·0715	+103·75	2	45·2463	......	......	......
2	72·4273	......	......	......	½	27·5213	5452	·1233	107·02
2	54·7191	......	......	......	2	27·2227	......	......	......
2	53·4771	·5009	0986	112·70	¼	15·6014	6224	1491	+115·40
2	53·0879	......	......	......	2	15·3776	......	......	......

Weighted mean .... +107·55
V_a.......... —17·50
V_d.................+ ·20
Curvature..— ·28

Radial velocity.. ....+ 90·0

ι ORIONIS 1268*

1908. Jan. 24.
G. M. T. 11h 40m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
1½	72·9861	....	....	....	2	45·2365	....	....	....
1½	72·9076	·9318	·0670	+ 97·22	1	27·5394	·5749	·1530	132·80
1½	72·4190	....	....	....	2	27·2115	....	....	....
2	54·7041	....	....	....	1	20·8613	·8955	·1149	93·53
1½	53·4778	5171	·1148	131·22	2	20·4859	....	....	....
2	53·0723	....	....	....	½	15·5531	·5890	·1157	+ 89·55
2	45·3066	·3437	·1050	109·62	2	15·3625	....	....	....

Weighted Mean............ .....+111·07
V_a........ ..... − 17·50
V_d..... ....+ ·20
Curvature... . . − ·28

Radial Velocity........ ... .+ 93·5

* Check measurement.

ι ORIONIS 1269.

1908. Jan. 24.
G. M. T. 11h 50m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^{ns}	Velocity.
2	73·0110	....	....	....	2	45·2762	....	....	....
1½	72·9546	·9530	·0882	+127·98	½	27·5563	5440	·1221	105·98
1½	72·4522	....	....	....	2	27·2590	....	....	....
2	54·0341	....	....	....	½	20·9592	·9417	·1611	131·13
1	53·4922	4895	·0872	99·67	2	20·5361	....	....	....
2	53·1137	....	....	....	½	15·6998	6834	·2101	+162·61
1	45·3617	·3591	·1204	125·70	2	15·4152	....	....	....

Weighted mean..... . ...+123·44
V_a...............— 17·50
V_d.......... . ...+ ·19
Curvature...... .— ·28

Radial velocity. . .. . +105·8

ι ORIONIS 1274.

1908. Jan. 24.
G. M. T. 14h 27m

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	54·7092	....	....	....	½	27·5182	·5372	·1153	100·07
1	53·4465	·4835	·0812	+ 92·86	2	27·2278	....	....	....
2	53·0742	....	....	....	½	15·5660	·5805	·1072	+ 83·00
1½	45·2736	·3050	·0663	69·20	2	15·3844	....	....	....
2	45·2423	....	....	....					

Weighted mean.................. +82·34
V_a.................. −17 50
V_d.................. ·00
Curvature........... − ·28

Radial velocity.................. + 64·6

ι ORIONIS 1274.*

1908. Jan. 24.
G. M. T. 14h 27m

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
1	54·7350	....	....	....	2	27·2528	....	....	....
1	53·4888	·4958	·0935	+106·92	1	20·9320	·9200	·1394	113·44
1	53·1048	....	....	....	2	20·5318	....	....	....
1	45·3146	·3208	·0821	85·68	¼	15·6166	·6032	·1300	+100·66
2	45·2675	....	....	....	2	15·3862	....	....	....
¼	27·5594	·5532	·1313	113·95					

Weighted mean..................+101·34
V_a.................. −17·50
V_d.................. ·00
Curvature........... − ·28

Radial velocity.................+ 84·5

* Check measurement.

ι ORIONIS 1275.

1908. Jan. 24.
G. M. T. $14^h\ 38^m$

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	72·9908	....	....	....	2	45·2533	.....	....	....
¼	72·9240	9429	·0781	+113·33	½	27·5626	·5620	1401	121·52
1	72·4261	....	....	....	2	27·2480	....	....	....
1	54·0097	....	....	......	¼	20·8872	·8962	1156	93·85
1	53·4694	4890	·0867	99·14	2	20·5297	....	....	....
2	53·0920	....	....	....	½	15·6614	·6500	1767	+136·76
½	45·3260	·3460	·1073	112·01	2	15·4106	....	....	....

Weighted mean	+112·02
V_a	17·50
V_d	− ·04
Curvature.... ..	− ·28
Radial velocity.. ..	+ 94·3

ι ORIONIS 1277

1908. Jan. 25.
G. M. T. $15^h\ 12^m$

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Dispt in revns	Velocity.
2	73·0765	....	....	....	¼	45·2179	·2356	·0031	− 3·23
½	72·9238	8578	0070	−10·16	¼	27·3695	·4275	0056	+ 4·86
1	72·5099	....	....	....	2	27·1868	.....	.....	......
2	54·0395	....	....	....	½	20·6785	7545	·0261	−21·24
½	53·3982	3887	·0136	15·55	2	20·4425	....	.....	......
2	53·1206	....	....	....	¼	15·4258	5038	·0305	+23·62
2	45·2559	....	....	.....	2	15·3079	.....	.....	....

Weighted mean...	− 7·63
V_a	−17·89
V_d	− ·09
Curvature.	− ·28
Radial Velocity	− 25·9

ι ORIONIS 1278.

1908. Jan. 25
G. M. T. 15h 27m

Observed by / Measured by } J. S. PLASKETT.

Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.	Wt.	Mean of Settings.	Corrected Star Setting.	Disp^t in rev^ns	Velocity.
2	73·0714	. .	. .	. .	½	45·2477	·2585	·0198	+20·66
½	72·9068	·8456	·0192	+27·86	¼	27·3824	·4330	·0111	+ 9·63
1	72·5051		. .	. .	2	27·1954		. . . .	. . . .
2	54·0384		. . .	. . . .	½	20·7192	·7860	·0054	+ 4·39
¼	53·4504	·4409	·0386	+44·15	2	20·4526		. . .	. . . .
2	53·1212	.	. . . .	. .	¼	15·4008	·4785	·0052	+ 4·02
2	45·2628	.	. . . .	.	1	15·3204	. . .	. . .	. .

Weighted mean . . . . . + 6·19
V_ι . . . . – 17·90
V_d 10
Curvature 28

Radial velocity . . . 12·1

PREVIOUS OBSERVATIONS OF ι ORIONIS.

Date.	Julian Day.	Velocity.	Phase.	Residuals C – O.
1903.				
Sept. 5·93	2,416,363·93	+21·	1·64	– 5
" 25·91	383·91	+40·	21·63	+15·
" 26·94	384·94	+57·	22·65	+ 4·
Oct. 17·97	405·97	+35·	14·55	–15
23·98	411·98	+42·	20·56	+ 7·
30·83	2,416,418·83	+90·	27·33	0·

ι ORIONIS.

Summary of Measures.

Brashear Spectroscope.

Plate Number.	Date.	Julian Day.	Velocities.	Weighted Mean.	Phase.	Residuals C—O
	1906					
453	Dec. 11·64	2,417,556·64	+ 116·		28·91	− 14·
485	" 18·58	563·58	− 22·		6·71	14·
	1907					
517	Jan. 2·63	578·63	+ 34		21·76	+ 22
522	" 9·61	585·61	+ 101		28·74	+ 1·
535	" 15·64	591·64	− 51		5·64	0·
539	" 16·64	592·64	6·		6·64	− 30·
556	" 18·65	594·65	+ 6·		8·65	− 25·
565	" 21·64	597·64	+ 21·		11·64	− 17·
570	" 22·67	598·67	+ 10·		12·67	0·
585	" 28·58	604·58	+ 43·		18·58	− 3·
587	" 30·52	606·52	+ 65	+ 56	20·59	− 16·
592	" 30·66	606·66	+ 48·			+ 1·
594	Feb. 4·51	611·51	+ 66·		25·51	+ 11·
601	" 6·64	613·64	+ 77·		27·64	+ 16·
605	" 7·51	614·51	+ 106·		28·51	− 6·
609	" 12·50	619·50	− 82		4·37	+ 7·
618	" 21·56	628·56	+ 9·		13·43	+ 5·
627	" 22·62	629·62	+ 22		14·49	− 1·
647	Mar. 6·51	641·51	+ 83·	+ 79·	26·44	+ 1·
650	" 6·64	641·64	+ 75			+ 9·
653	" 8·52	643·52	+ 106	+ 108·	28·45	− 6·
655	" 8·64	643·64	+ 109·			− 9·
659	" 11·54	646·54	− 101	− 112·	2·34	0·
662	" 11·64	646·64	122·			+ 7·
665	" 20·52	655·52	+ 13·			− 11·
666	" 20·54	655·54	+ 15·	+ 13·	11·31	− 13·
667	" 20·61	655·61	+ 11			− 9
672	" 26·52	661·52	+ 33		17·27	+ 1·
673	" 28·52	663·52	+ 40·		19·27	− 3·
678	" 30·53	665·53	+ 62·		21·28	− 9·
686	April 3·54	669·54	+ 70	+ 66·	25·30	+ 5·
687	" 3·56	669·56	+ 61·			+ 14·
693	" 5·52	671·52	+ 86	+ 76·	27·28	+ 4·
695	" 5·55	671·55	+ 67			+ 13·
702	" 6·52	672·52	+ 90	+ 99·	28·27	+ 8·
703	" 6·53	672·53	+ 107·			− 9·
705	" 11·53	677·53	− 89·		4·14	+ 9·

Single-Prism Spectroscope.

Plate Number.	Date.	Julian Day.	Velocities.	Weighted Mean.	Phase.	Residuals C—O
1046	Sept. 14·86	833·86	+ 38· H + 31· P	+ 35·	14·76	− 13·
1059	" 18·93	837·93	+ 33·		18·83	
1069	" 20·89	839·89	+ 66·	+ 57·	20·80	− 15·
1070	" 20·90	839·90	+ 48·			+ 3·
1076	" 30·89	849·89	+ 26·			− 6·
1077	" 30·91	849·91	+ 26·	+ 30·	1·68	− 6·
1078	" 30·92	849·92	+ 30			− 10·
1079	" 30·93	849·93	+ 37·			− 17·
1097	Oct. 8·85	857·85	− 6·		9·61	− 15·
1108	" 28·94	877·94	+ 111·	+ 104·	0·59	− 9·
1109	" 28·96	877·96	+ 97·			+ 5·
1110	" 29·85	878·85	+ 28· H			+ 11·
...	...	...	+ 32· W			+ 7·
1111	" 29·87	878·87	+ 37·			+ 4·
1112	" 29·89	878·89	+ 38·	+ 34	1·54	+ 2·
1113	" 29·92	878·92	+ 36			+ 0·
1114	" 29·95	2,417,878·95	+ 26·			+ 4·

SUMMARY OF MEASURES—*Continued.*

Plate Number.	Date.	Julian Day.	Velocities.	Weighted Mean.	Phase.	Residuals C—O.
1115........	Oct. 30·78	2,417,879·78	− 111			− 5·
1116........	″ 30·80	879·80	− 120·	−114·	2·45	+ 3
1117........	″ 30·82	879·82	− 114·			− 4·
1118........	″ 30·85	879·85	− 112·			− 7·
1119........	″ 30·88	879·88	119·	−124·	2·53	− 1·
1120........	″ 30·90	879·90	− 129			+ 9·
1121........	″ 31·78	880·78	− 93·			− 7
1122........	″ 31·82	880·82	− 78·	− 85·	3·46	−21·
1123........	″ 31·86	880·86	− 84·			− 4
1124........	Nov. 1·77	881·77	− 81·			+ 9·
1125........	″ 1·81	881·81	− 62·			−10·
1126........	″ 1·83	881·83	− 97· W	− 71·	4·45	+25·
....	....	....	− 89· P			+17
1127........	″ 1·85	881·85	− 52·			−18·
1136........	″ 11·77	891·77	+ 17· W			+ 3·
....	....	....	+ 16· H	+ 22·	14·43	+ 4·
1137........	″ 11·79	891·77	+ 28·			− 8·
1141........	″ 15·75	895·75	+ 27·			+10·
1142........	″ 15·76	895·76	+ 28·	+ 31·	18·40	+11
1143........	″ 15·77	895·77	+ 37			+ 2·
1147........	″ 16·73	896·73	+ 45·	+ 42·	19·38	− 4·
1148........	″ 16·75	896·75	+ 39·			+ 2·
1161........	″ 28·88	908·88	− 126· W			+12·
....	....	....	− 104· P			−10·
....	....	....	− 120· H	−115	2·40	+ 6·
1162........	″ 28·90	908·90	− 144· W			+30·
....	....	....	− 109· P			− 5·
....	....	....	− 115· H			+ 1·
1166........	″ 29·90	909·90	− 85·			−15·
1167........	″ 29·91	909·91	− 131· W	−111·	3·40	+31·
....	....	....	− 114· H			+14·
1168........	Dec. 3·64	913·64	− 38·			− 7·
1169........	″ 3·65	913·65	− 9·	− 27·	7·14	+20
1170........	″ 3·66	913·66	− 26·			+ 5·
1178........	″ 4·73	914·73	− 15·	....	8·23	− 6·
1188........	″ 21·65	931·65	+ 71·	+ 76·	25·20	+ 5·
1189........	″ 21·76	931·76	79·			− 3·
1190........	″ 24·66	934·66	+ 104·	....	.... 28·14	+ 4·
1191........	″ 28·54	938·54	− 104·			+12·
1192........	″ 28·63	938·63	− 117·	− 116·	3·00	− 4·
1193........	″ 28·64	938·64	− 114·			− 1·
1194........	″ 28·64	938·64	− 123·			+ 9·
1201........	″ 28·82	938·82	− 113·	− 118·	3·18	+ 5·
1202........	″ 28·82	938·82	− 123·			+15·
1203........	″ 30·81	940·81	− 43·	− 46·	5·17	−14·
1204........	″ 30·82	940·82	− 49·			− 8·
	1908.					
1206........	Jan. 1·74	942·74	− 31·	− 28·	7·10	+ 1
1207........	″ 1·75	942·75	− 24·			− 7·
1212........	″ 3·61	944·61	− 2·	− 6·	8·98	−16·
1213........	″ 3·62	944·62	− 9·			− 5·
1219........	″ 10·73	951·73	+ 36·	....	6·09	− 8·
1258........	″ 22·69	963·69	+ 64· W			+32·
....	....	....	+ 93· H			+ 3·
1259........	″ 22·71	963·71	+ 79· W	+ 81·	28·06	+17·
....	....	....	+ 77· H			+19·
1262........	″ 23·56	964·56	+ 99· W			+ 4·
....	....	....	+ 108· P			− 5·
1263........	″ 23·57	964·57	+ 95· W	+102·	28·94	+ 8·
....	....	....	+ 113· H			−10·
1265........	″ 23·60	964·60	+ 112·			− 9·
1266........	″ 23·60	964·60	+ 82·			+21·
1267........	″ 24·49	965·49	+ 107·			− 6·
1268........	″ 24·49	965·49	+ 90· W	+101·	0·71	+12·
....	....	....	+ 94· H			+ 8·
1269........	″ 24·50	965·50	+ 106·			− 4·

SUMMARY OF MEASURES—*Concluded.*

Plate Number.	Date.	Julian Day.	Velocities.	Weighted Mean.	Phase.	Residuals C.-O.
	1908.					
1274	Jan. 24·60	2,417,965·60	+ 6 W			+28·
..	....	....	+ 84· H	- 85	0·82	+ 9
1275	24·60	965·60	· 94			− 1·
1277......	" 25·63	966·63	26	- 19	1·85	+ 6·
1278.	" 25·64	2,417,966·64	− 12			− 8·

PHASES AND VELOCITIES.

Phase.	Mean Velocity.	No. of Plates.	Phase.	Mean Velocity.	No. of Plates.
0·65	+101·3	5	14·53	+ 27·4	5
0·82	+ 91·0	2	16·67	+ 34·7	2
1·60	+ 30·8	10	18·44	+ 34·3	4
1·85	− 21·3	2	19·32	+ 41·2	2
2·43	115·7	10	20·67	+ 51·2	5
3·07	118·2	5	21·65	+ 45·3	3
3·44	92·1	5	22·65	+ 57·0	1
4·39	− 75·7	6	25·30	+ 70·0	5
5·33	− 47·8	3	26·44	+ 79·0	2
6·68	14·0	2	27·39	+ 80·0	4
7·12	− 27·3	5	28·16	+ 92·1	5
8·89	2·1	5	28·53	+105·5	4
11·39	+ 15·0	4	28·93	+104·9	5
13·05	+ 9·5	2			

As previously stated, the observations corresponding to the velocities given in columns 4 and 5 and the phases in column 6 of the table containing the summary of measures, are plotted in Fig. 4, where the single circles represent single observations and the double circles the weighted means of two or more observations on the same night. The grouped results in the succeeding table of observations grouped in phases are plotted in Fig. 5. The full line curve in the latter figure is the velocity curve for an eccentricity e of 0·75, a longitude of the apse ω of 110° and a double amplitude $2K$ of 224 kms., which are the values chosen for the elements as best agreeing with the observations.

Owing to the considerations previously mentioned, especially that relating to the possibility of a secondary disturbance, a final determination of the elements by the usual methods is out of the question. They only suffice to give preliminary values which must be corrected by a species of trial and error. For this purpose, the application of your method of obtaining elements to the construction of an ephemeris and the drawing of the velocity curve or to changing these to correspond to changes in the elements has been found very useful as the labour involved therein is reduced to a minimum.

No simple elliptic orbit will give a velocity curve agreeing with a smooth curve drawn as closely as possible through the observed points, and we are forced to the conclusion, either that the differences are due to errors in the observations or to secondary disturbances in the orbit. The latter seems to be the most likely, for, although it is probable enough that two or three observations may be in error to the extent shown by the figure, it is hardly possible that for 10 or 12 days before apastron passage the residuals should be almost wholly negative, and for 10 or 12 days after almost wholly positive.

These residuals can be considerably reduced and a curve agreeing fairly well with the observations on the ascending branch may be obtained by increasing the eccentricity to about 0·82. An eccentricity of 0·80 is shown by one of the dotted curves in Fig. 5. The use of an eccentricity of even 0·80 produces much higher residuals on the rapidly descending branch and at the points of maximum and minimum velocity, than an eccentricity of 0·75 in the ascending branch. In the descending branch any errors of observation or even any moderate secondary disturbance would have very little effect on the position or inclination of the curve. It was, therefore, considered preferable to determine the eccentricity by the inclination of the curve around periastron rather than by agreement around apastron, and it was for this purpose that observations in that phase were so long awaited. A reference to the curves of oscillation, Fig. 3, for e = 0·70, 0·75 and 0·80 shows that the eccentricity can be determined to within 0·01 by the inclination of the descending branch, and it may be stated that the same criterion may be used to determine the eccentricity whatever the value of ω. Furthermore the value of ω is also closely limited by the position of the curve near apastron. A difference of 1° either way would displace the curve too far up or down for the best agreement with the observations.

The above considerations led to the final choice of the elements $e = 0{\cdot}75$ $\omega = 110°$ as the most probable, while the question of a secondary curve is left open. The observations, even taking into account their high probable error, indicate the presence of such a curve, but do not sufficiently define its position and amplitude to enable any explanation of its cause to be assigned. So far as known to the writer, previously discovered secondary disturbances have been submultiples of the main period, but such is apparently not the case here where the secondary effect persists for 10 or 12 days on each side of apastron, about three-fourths of the period. An attempt was made to establish some connection between the asymmetric nature of the lines, maximum to red or violet, and the position in the period, but nothing definite was obtained. It is evident, however, that a very slight shift of the position of the maximum, one indeed that would be scarcely noticed in the broad and diffuse lines of this spectrum, would be quite sufficient to account for residuals of the magnitude present on each side of apastron. Such a shift of the maximum might reasonably be assigned to some physical change in the star's atmosphere without the necessity of considering the secondary curve to be due to any deviations from an elliptic orbit caused by the presence of a third body. These, however, are speculations which cannot, from the data available, become anything more.

The remaining elements of the orbit are easily obtained by the well known methods when, as here, the values of e, ω, K and T are known.

$e = 0{\cdot}75$.
$\omega = 110°$.
Positive maximum = + 104.
Negative maximum = − 120.
$K = 112$.
$T = 1{\cdot}94$ days = Julian day 2,417,587·94.
γ or velocity of system = + 20·7 kms.
$a \sin i = 29{,}680{\cdot}000$ kms.

A diagram of the orbit showing the proportions of the system is given in Fig. 6.

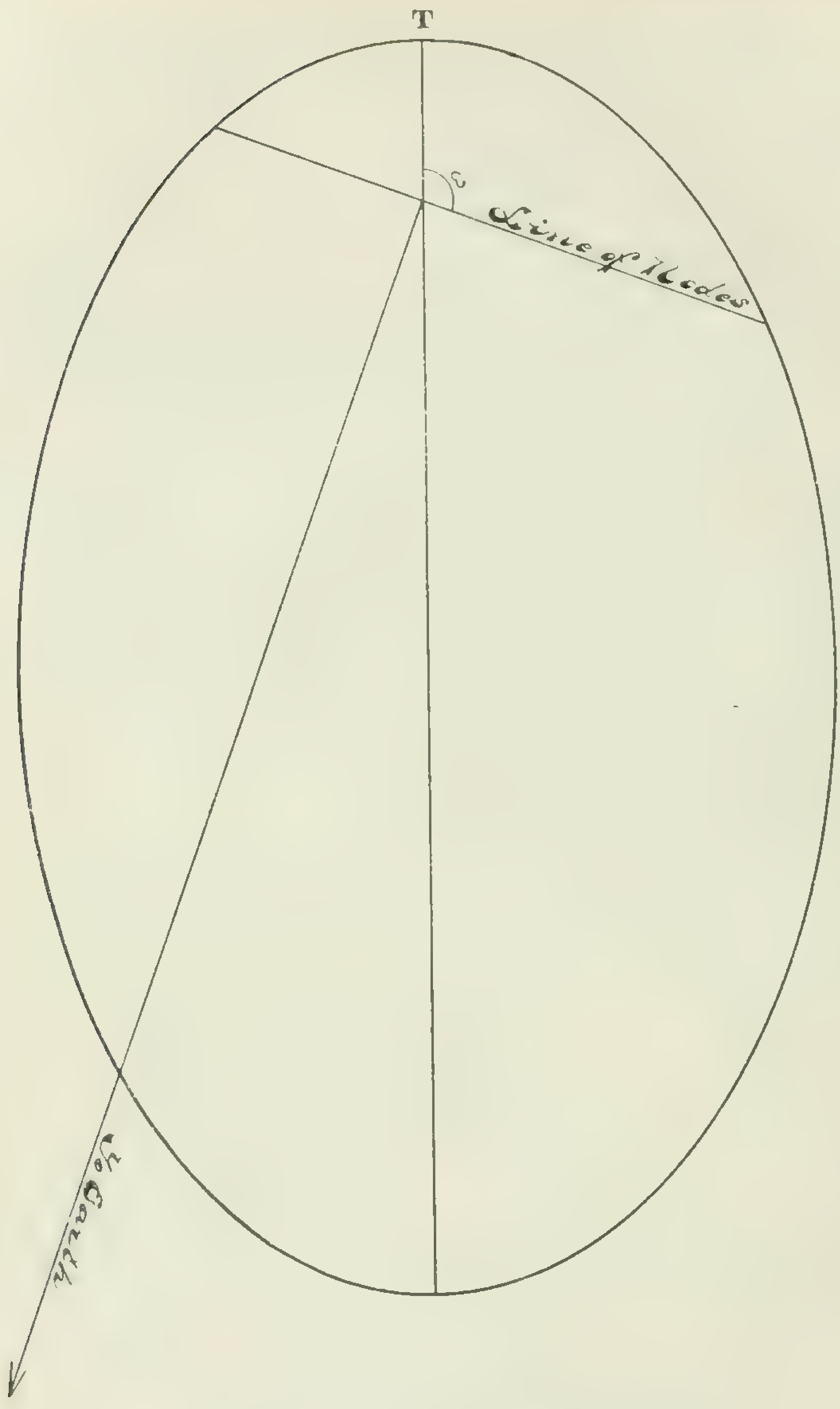


FIG. 6—Orbit of ι Orionis.

Although the agreement between the observations and the computed curve is not as good as might be wished, it is doubtful whether much improvement would be effected by continuing the observations at present. The character of the spectrum is such that there must necessarily always remain an uncertainty to the extent of 10 kilometres or so in the velocity value of any plate and, unless a great number of observations were obtained at most of the phases in the last table, the question would still remain uncertain. It would undoubtedly be of interest, in the course of a few years, to redetermine the elements to see if any definite change in the form of the curve has taken place.

Addendum.

Since the above was written, Dr. Schlesinger, Director of the Allegheny Observatory, kindly suggested to me the advisability of applying a least squares solution to this orbit, and as the result of this computation showed considerable improvement over the geometrical methods it is herewith given.

As a preliminary to this work, all the observations were again carefully gone over and weighted as consistently as possible, giving those made by the Universal spectroscope only about half the weight of the later plates. The period was considered as closely determined by the method previously described. In the grouping into normal places some of the velocities and phases were slightly changed by the new weighting and the number diminished by one, making 26, as shown in the following table of normal places and residuals. Taking as provisional values of the elements those given above, an ephemeris was computed, the residuals between the observed and computed velocities obtained, and the coefficients of the unknowns calculated from the formula of Lehmann-Filhes.*

$$\delta\frac{dz}{dt} = (\cos u + e\cos\omega)\,\delta K + \left\{\cos\omega - \frac{\sin u \sin v}{1-e^2}(2 + e\cos v)\right\} K\delta e$$
$$-(\sin u + e\sin\omega)\,K\delta\omega - \sin u\,(1 + e\cos v)^2\,(t-T)\frac{K\delta\mu}{(1-e^2)^{3/2}}$$
$$+\sin u\,(1+e\cos v)^2\frac{K\mu\,\delta T}{(1-e^2)^{3/2}}$$

The coefficient of $\delta\mu$ was omitted as the period was considered final and an additional unknown of coefficient unity was introduced as a correction for the velocity of the system.

There result the following 26 observation equations in which for homogeneity we put

$$x = \delta K$$
$$y = K\delta e = 112\cdot\ \delta e$$
$$z = K\delta\omega = 112\cdot\ \delta\omega$$
$$u = \frac{K\mu\,\delta T}{(1-e^2)^{3/2}} = 83{\cdot}46\ \delta T$$
$$v = \delta\gamma$$

* A. N. No. 3242.

OBSERVATION EQUATIONS FOR 1st SOLUTION.

x	y	z	u	v	n	Wt.
+ ·717	− ·648	− ·933	+ ·189	+1·000	+ 4·0	7
·081	− ·612	1·646	+ ·234	−1·000	1·0	10
·415	·826	1·692	+ ·299	+1·000	− 6·7	2
1·228	−1·425	·940	·472	1·000	− 0·1	9
−1·178	−1·396	− ·317	·360	−1·000	+ 4·7	6
1·072	−1·955	− ·127	− ·372	+1·000	− 4·2	4
·838	+2·074	− ·109	·270	+1·000	+ 3·0	5
·689	−1·832	− ·197	− ·204	−1·000	− 8·5	3
·511	−1·401	+ ·262	− ·142	+1·000	−22·5	1
·466	−1·279	− ·273	·130	−1·000	− 6·1	5
·323	− ·868	− ·293	·098	−1·000	− 5·9	4
·161	− ·384	·291	·075	−1·000	−12·3	2
·074	− ·124	− ·278	·067	+1·000	+ 2·9	1
·004	·084	− ·263	− ·062	−1·000	− 5·5	4
− ·084	·338	− ·235	·059	−1·000	− 5·1	2
·173	− ·586	+ ·198	− ·058	−1·000	+ 7·2	4
+ ·209	·685	+ ·180	− ·058	+1·000	+ 2·3	3
+ ·270	− ·842	+ ·146	− ·059	−1·000	− 0·7	4
+ ·308	− ·938	+ ·121	− ·052	+1·000	+11·2	2
+ ·358	1·056	− ·084	·065	+1·000	+ 3·9	1
+ ·496	1·315	− ·046	− ·077	+1·000	+ 4·5	3
+ ·567	1·386	·137	− ·086	−1·000	+ 5·2	1
+ ·628	1·376	·239	− ·092	+1·000	+ 9·5	2
+ ·681	−1·259	·357	− ·092	−1·000	+ 6·8	4
− ·708	1·112	− ·442	− ·085	+1·000	− 5·7	2
+ ·730	0·867	− ·544	− ·065	+1·000	+ 0·2	4

From these observation equations were obtained the following normal equations:—

$$
\begin{aligned}
+44{\cdot}968x - 29{\cdot}522y + 3{\cdot}3222z + 0{\cdot}327u - 14{\cdot}291v + 98{\cdot}606 &= 0\\
+228{\cdot}507y - 41{\cdot}899z + 65{\cdot}630u + 39{\cdot}089v - 244{\cdot}074 &= 0\\
+51{\cdot}724z - 53{\cdot}431u - 33{\cdot}929v - 33{\cdot}442 &= 0\\
+76{\cdot}940u + 25{\cdot}424v - 56{\cdot}373 &= 0\\
+95{\cdot}000v - 15{\cdot}800 &= 0
\end{aligned}
$$

Their solution gives

$x=-2{\cdot}084$	$\delta K=-2{\cdot}084$ km.
$y=+\ {\cdot}5827$	$\delta e=+\ {\cdot}0052$
$z=+6{\cdot}0337$	$\delta\omega=+\ {\cdot}0539\ =3^\circ{\cdot}31$
$u=+4{\cdot}2237$	$\delta T=+\ {\cdot}051$
$v=+\ {\cdot}6376$	$\delta\gamma=+\ {\cdot}64$ km.

from which the corrected elements.

	Preliminary.	Corrected.
K.	112·0	109·92
e.	0·75	0·7552
ω.	110°	113°·31
T.	1·94 dys.	1·991 dys.
γ.	20·7 km.	21·34 km.
Period.	20·136 dys.	29·136 dys.
$a \sin i$.	29,680,000 km.	28,867,000 km.

When an ephemeris was computed from these elements it was found that the residuals obtained did not agree closely enough with those obtained by substitution in the observation equations, the differences in some cases being upwards of a kilometre and a second solution became necessary. It was found that changing T from 1·99 to 2·01 days improved the agreement somewhat and this change was made for the second provisional elements, the others being those determined from the first solution.

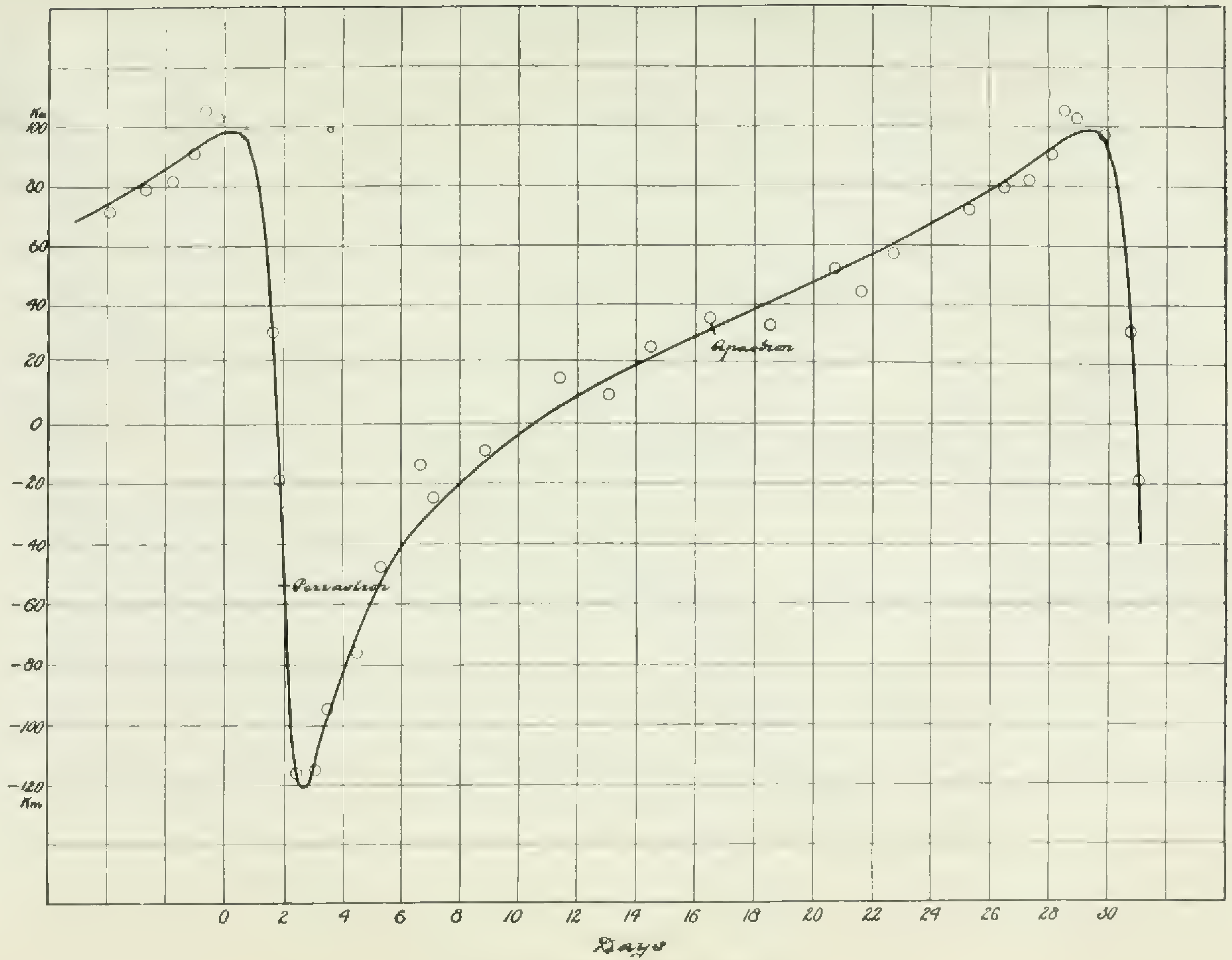


Fig. 7—Velocity Curve ι Orionis.

Making the same substitutions for homogeneity as before we get the following observation equations.

OBSERVATION EQUATIONS FOR 2ND SOLUTION.

x	y	z	u	v	n	Wt.
+ ·677	+ ·542	·914	+ ·163	+1·000	1·29	7
+ ·124	+3·547	−1·599	+2·042	+1·000	+ 4·28	10
− ·335	+1·883	−1·693	+2·901	+1·000	+ 3·52	2
−1·263	−1·582	− ·958	+ ·572	+1·000	− 0·83	9
1·208	+1·526	− ·277	·402	+1·000	+ 4·45	6
1·088	+2·108	− ·079	·403	+1·000	3·06	4
− ·833	+2·159	+ ·152	·278	+1·000	+ 5·83	5
·678	1·868	+ ·232	− ·206	+1·000	5·18	3
− ·495	+1·393	+ ·287	− ·141	+1·000	19·11	1
+ ·449	+1·260	+ ·295	− ·128	+1·000	− 2·64	5
− ·306	+ ·820	+ ·306	− ·095	+1·000	− 2·83	4
− ·146	+ ·335	+ ·295	− ·071	+1·000	− 9·71	2
·061	+ ·075	+ ·278	− ·063	+1·000	+ 5·15	1
+ ·008	− ·133	+ ·258	− ·059	+1·000	− 3·62	4
+ ·093	− ·384	+ ·227	− ·055	+1·000	− 3·77	2
+ ·178	·625	+ ·186	− ·054	+1·000	+ 7·97	4
+ ·215	− ·720	+ ·166	− ·054	+1·000	+ 2·89	3
+ ·268	− ·866	+ ·130	− ·055	+1·000	− 0·79	4
+ ·306	− ·961	+ ·103	− ·057	+1·000	+11·01	2
+ ·354	−1·071	+ ·064	− ·059	+1·000	+ 3·23	1
+ ·482	−1·306	·068	− ·069	+1·000	+ 2·57	3
+ ·547	−1·353	·159	− ·070	+1·000	+ 2·42	1
+ ·602	−1·342	·260	− ·080	+1·000	+ 5·73	2
+ ·649	1·233	− ·375	·078	+1·000	+ 2·47	4
+ ·672	−1·078	·456	− ·071	+1·000	10·44	2
+ ·691	·845	− ·553	− ·052	+1·000	− 4·98	4

Whence the normal equations

$$
\begin{aligned}
+45{\cdot}058x - 28{\cdot}047y + 2{\cdot}576z + 0{\cdot}726u - 14{\cdot}660v - 0{\cdot}731 &= 0\\
+266{\cdot}994y - 45{\cdot}686z + 65{\cdot}208u + 43{\cdot}697v + 117{\cdot}502 &= 0\\
+50{\cdot}372z - 48{\cdot}247u - 33{\cdot}053v - 70{\cdot}762 &= 0\\
+64{\cdot}085u + 22{\cdot}897v + 95{\cdot}820 &= 0\\
95{\cdot}000v + 34{\cdot}800 &= 0
\end{aligned}
$$

Their solution gives

$$
\begin{aligned}
x &= -\ {\cdot}0193 & \delta K &= -\ {\cdot}0193 \text{ km.}\\
y &= -\ {\cdot}1014 & \delta e &= -\ {\cdot}00092\\
z &= -\ {\cdot}0674 & \delta\omega &= -\ {\cdot}00061 \quad = -\ {\cdot}035^\circ\\
u &= -1{\cdot}4430 & \delta T &= -\ {\cdot}0172 \text{ dys.}\\
v &= -\ {\cdot}0018 & \delta\gamma &= -\ {\cdot}0018 \text{ km.}
\end{aligned}
$$

Whence the final elements.

$K = 109{\cdot}90 \quad \pm 1{\cdot}100$ km.
$e = 0{\cdot}7543 \quad \pm {\cdot}0046$
$\omega = 113^\circ{\cdot}28 \quad \pm 1^\circ{\cdot}083$
$T = 1{\cdot}993 \quad \pm 0{\cdot}022$ dys. = Julian day 2,417,587·993.
Period=29·136 days.
$a \sin i$ = 28,907,000 km.

An ephemeris computed from these elements shows that Σpvv has been reduced from 2994 to 2181, the probable error of an observation of unit weight becoming ±6·88 km., while the probable errors of the elements are those given above. The velocity curve corresponding to the final elements is given in Fig. 7. The changes from the first solution are very small but have resulted in a satisfactory agreement

of the residuals (see accompanying tables) obtained on the one hand from an ephemeris computed from the final elements, and on the other by substitution of the values of the unknowns in the observation equations.

NORMAL PLACES AND RESIDUALS.

Mean Phase.	Mean Velocity.	Residuals O - C.				
		Preliminary.	1st Solution.	2nd Solution.	By Substitution.	Eph. - Eq.
0 71	+ 97·0	— 4·0	+ 1·29	+ 1·54	+ 1·52	+ ·02
1 61	+ 30·8	+ 1·0	— 4·28	— 1·23	— 1 08	15
1 85	+ 19·0	+ 6·7	— 3·52	+ ·70	+ ·74	— ·04
2 44	-116·7	+ 0·1	+ 0·83	+ 1·37	+ 1·39	— ·02
3 06	—115·9	— 4 7	— 4·45	— 4·93	— 4·91	— ·02
3·44	95·2	+ 4·2	+ 3·06	+ 2·67	+ 2·67	·00
4 42	— 76·1	— 3·0	— 5 83	— 6·02	- 6·01	·01
5 27	— 48·0	+ 8·5	+ 5·18	+ 5·09	+ 5·09	·00
6·68	- 14 0	+22·5	+19·11	+19·03	+19·06	— ·03
7 12	- 25·4	+ 6·1	+ 2·64	+ 2 68	+ 2 60	+ ·08
8 83	— 9·5	+ 5 9	+ 2·83	+ 2·78	+ 2·78	·00
11 39	15·0	+12·3	+ 9·71	+ 9·64	+ 9 66	— 02
13·05	9·5	— 2·9	— 5·15	— 5 24	- 5·21	— ·03
14·52	25 8	+ 5·5	+ 3·62	+ 3·55	+ 3·55	·00
16 48	35·3	+ 5·1	+ 3·77	+ 3·65	+ 3·67	·02
18 52	32·9	— 7·2	— 7·97	— 8·09	— 8·10	+ ·01
19 36	41·8	— 2·3	— 2·89	— 3·02	— 3·03	+ 01
20·69	51·6	+ 0·7	+ 0·79	+ ·63	+ ·64	— ·01
21·58	44·0	—11·2	—11·01	—11·18	—11·17	— ·01
22 65	57·0	— 3·9	— 3·23	— 3·42	— 3·41	— ·01
25·27	71·7	— 4·5	— 2·57	— 2·89	— 2·79	— ·10
26 44	79·0	— 5·2	— 2·42	— 2·68	— 2·66	— ·02
27 37	81·8	— 9·5	- 5·73	— 6·00	— 6·00	·00
28·13	90·2	— 6·8	— 2·47	— 2·72	— 2·73	+ ·01
28 54	105·7	+ 5·7	+10·44	+10·21	+10·21	·00
28·93	102 3	— 0·2	+ 4·98	+ 4·80	+ 4·79	+ ·01

The principal change from the original elements is in K and ω, the former being diminished by 2·1 kms., and the latter increased by 3°·28. As a result of these changes, and shown by comparison of the velocity curves, the general trend of the observations is more closely followed. The probability of a secondary disturbance seems somewhat less than with the original elements, and this is further lessened by a knowledge of the fact that in the normal places with the highest residuals there are always one or more observations with the Universal spectroscope where the temperature control was poor and the spectra contained only two measurable lines. This computation has effected apparently considerable improvement in the elements and seems to justify Dr. Schlesinger's contention that the least squares solution will always, even in the case of inaccurate observations, give the best elements .

The Spectroscopic Binary ψ Orionis.

The star ψ Orionis, R. A. 5h. 21·6m. Dec. + 3° 1′ Phot. Mag. 4·5 was announced by Frost and Adams* as a spectroscopic binary in 1903, and upon learning that the discoverers were not following it up, and with their consent, it was placed under observation here on November 11, 1907, while the last plate was made on March 16, 1908. In all 37 plates have been measured for the determination of its orbit. Its spectrum is of the helium type with broad and diffuse lines, but is nevertheless much easier of measurement than the spectrum of ι Orionis above discussed. The lines though diffuse are not in general asymmetric, and the place of setting is, as a rule,

* Astrophysical Journal, Vol. XVII., p. 246.

considerably more certain than in ι Orionis. Moreover, the number of lines visible and measurable in ψ Orionis is considerably larger than in ι Orionis. To this must be added the fact that, as its orbit is nearly circular, the changes in the velocity curve which is consequently nearly a sine curve, are gradual and uniform, and its position, therefore, more easily defined than in the case of high eccentricity where the form of curve changes abruptly. For accurate determination of the elements, observations must be carefully grouped about this position of abrupt change and, as in ι Orionis, this is frequently difficult to attain. No such difficulty was met with in ψ Orionis, and the observations, taken through the winter whenever possible, seemed to group themselves suitably for the determination of the elements.

Some little difficulty was at first met with in obtaining the period. It was soon seen that it was comparatively short and, as high positive and negative values repeated themselves at intervals of 5 days, this period was first tried. No adjustment of the observations, however, could make them suit this period, and submultiples of it were then tested. When the observations were grouped into a period of 2½ days, some signs of definite arrangement manifested themselves which a slight lengthening of the period improved. Further trials showed that a period of 2·526 days suited our own observations better than either 2·525 or 2·527 days and, on bringing up Frost and Adams'* early observations a suitable number of periods, this was finally fixed at 2·5259 days, which can not be much in error.

All the lines measured in the spectrum of ψ Orionis, both star and comparison with the micrometer readings corresponding, and the velocities per revolution are given in the following table:—

LINES USED IN MEASUREMENT OF Ψ ORIONIS.

Star Lines.				Comparison Lines.	
Element.	Wave-Length.	Micometer Reading.	Vel. per Rev.	Wave-Length.	Micrometer Reading.
H...............	4861 527	72·8648	1451 2	4864·943	73·0098
He.............	4713·308	66·1879	1332·4	4851·686	72·4449
He...............	4471 676	53·4023	1143·5	4494·755	54·7419
He	4388·100	48 3107	1079·7	4482·413	54 0288
H	4340·634	45·2387	1043 7	4466·737	53·1120
He..............	4143·928	30·8756	898·2	4395·382	48·7700
He...............	4120·973	29·0038	881·3	4341 162	45·2736
H..............	4102·000	27·4219	867·9	4143·863	30·8704
He...............	4026·352	20·7806	813·8	4099·921	27·2466
H	3970·177	15·4733	774·3	4023·508	20·5200
....	....	....	....	3969·411	15·3986

The programme of observations will be followed by the detailed measures. It will be noticed that several of the plates have been remeasured by different observers. The original measures in some cases showed residuals from the curve higher than was expected and those with the largest residuals have been remeasured, without, however, in general, making much change in the velocity.

* Astrophysical Journal, Vol. XVII, p. 246.

RECORD OF SPECTROGRAMS.

Star.	No. of Negative.	Camera.	Plate.	Date.	Middle of Exposure E. S. T.	Duration.	Hour Angle at end.	Comparison Spectrum. Exposures in seconds.	Comparison Spectrum. Kind.	Temperature Centigrade. Room. Beginning.	Temperature Centigrade. Room. End.	Temperature Centigrade. Prism Box. Beginning.	Temperature Centigrade. Prism Box. End.	Slit Width.	Focal Position. Star Focus.	Focal Position. Collimator.	Focal Position. Camera.	Seeing.	Observer.
				1907.	h m	m	h m												
ψ Orionis..	1138	IL	Seed 27.	Nov. 11	3 04	72	1 35 W	6 10 6	FeV spark	— 2·0	— 3·0	5·5	5 5	·0014	73 5	10 8	18·2	Fair . .	H
" ..	1158	"	" 27.	" 23	12 12	45	0 40 E.	4 — 7 4	" .	— 0 3	— 0 2	6 7	6 7	·0013	74 0	10·8	18·18	"	P
" ..	1182	"	" 27	Dec. 4	2 46	45	2 35 W	4 4 4 4	" .	—12·4	—13 0	1 1	1·0	·0015	72 0	10·8	18.1	Good.	P
" ..	1183	"	" 27.	" 4	3 31	47	3 25 W.	4 4 4 4	"	—13 4	—13 0	0 9	0 9	·0015	72 0	10·8	18 1	" ...	P
"	1195	"	" 27.	" 28	11 00	40	0 20 W.	5 5 5 5	"	— 5·6	— 5·8	3·1	3·1	·0013	73·5	10·8	18·1	" ...	P
" .	1196	"	" 27.	" 28	11 45	40	1 05 W	5 5 5 5	" .	— 5·6	— 5·8	3 1	3 1	·0016	73·5	10·8	18 1	"	P
				1908.															
" ..	1208	"	" 27	Jan. 1	1 20	35	2 55 W.	4 4 -3 3	" .	— 8·0	— 7 5	— 5·6	— 5 7	·0013	72 5	10 8	18·1	" ...	P
" ..	1209	"	" 27.	" 1	2 00	35	3 35 W.	4 4 -3 -3	" .	— 7 5	— 7 8	— 5·7	— 5 7	·0013	72·5	10·8	18·1	" ...	P
" ..	1214	"	" 27.	" 3	10 21	47	0 10 W	3 -3 3 3	" .	— 7 6	— 7·4	— 4·4	— 4 4	·0013	72·6	10·8	18·1	Fair .	P
" ..	1215	"	" 27	" 3	11 01	30	0 40 W.	2 2 -2 2	" .	— 7 5	— 8 4	— 4·4	— 4 4	·0013	72·6	10·8	18 1	" .	P
" ..	1220	"	" 27	" 13	12 26	33	2 45 W.	2 2 2 2	" .	— 9·3	— 9 5	0 0	0·0	·0013	72·5	10·8	18·12	" ...	P
" .	1221	"	" 27.	" 13	1 00	30	3 15 W.	1½ 1½ 1½-1½	" .	— 9·5	— 9·5	0·1	— 0·2	·0013	72 5	10·8	18·12	" ...	P
" .	1227	"	" 27.	" 14	8 21	43	1 12 E.	1 1 -1 -1	" .	—11·5	—11·0	— 5 1	— 5 1	·0013	72 5	10·8	18·05	Good. .	H
" ..	1233	"	" 27.	" 16	6 55	35	2 35 E.	1¼ 1¼ 1¼-1¼	"	—12·0	—13 0	— 6 0	— 6 0	·0013	72 0	10 8	18 05	Unsteady.	P
" ..	1238	"	" 27.	" 20	7 57	65	1 00 E.	1½ 1½ 1½ 1½	" .	— 9·4	— 8·8	— 6·8	— 6 8	·0013	72·5	10·8	18·07	Very bad.	P
" ..	1239	"	" 27.	" 20	8 53	43	0 15 E.	1½-1½ 1½ 1½	" .	— 8 8	— 7·0	— 6·8	— 6·8	·0013	72·5	10·8	18·07	Poor ..	P
" .	1257	"	" 27.	" 22	10 29	33	1 25 W.	2 2 2	" .	— 8·0	— 8·0	0·1	0·2	·0013	72·5	10·8	18·09	Good ...	H
" ..	1264	"	" 27.	" 23	9 03	30	0	1¼ 1¼ 1¼ 1¼	" .	—11·0	—12·6	— 5·3	— 5 3	·0013	72·5	10·8	18·03	Fair	P
" ..	1271	"	" 27	" 24	7 49	32	1 10 E.	1¼-1¼-1¼ 1¼	" .	—14·8	—15·5	— 9·0	— 9 0	·0013	72·0	10·8	18·0	" .	P
" .	1279	"	" 27.	" 27	6 42	35	2 00 E.	1¼ 1¼ 1¼-1¼	" .	—12 7	—12·7	—11·1	—11·1	·0013	72 0	10 8	18·06	"	P
" ..	1283	"	" 27.	" 27	9 21	30	0 33 W.	1¼ 1¼-1¼ 1¼	"	—14·0	—13 0	—11·1	—11·1	·0013	72·0	10·8	18·06	Good. ...	P
" ..	1296	"	" 27.	" 29	6 00	35	2 35 E.	1½ 1½ 1½ 1½	" .	—16 0	—16·6	— 8·1	— 8·1	·0013	72·4	10 8	18·08	Unsteady.	P
" ..	1301	"	" 27.	" 29	10 01	41	1 27 W.	1½-1½-1½ 1½	" .	—22·0	—22·3	— 8·6	— 8·7	·0013	72 4	10·8	18·08	" .	H
" .	1304	"	" 27.	" 29	12 02	42	3 26 W.	1½ 1½ 1½ 1½	" .	—23·0	—23·5	— 8·6	— 8·6	·0013	72·4	10·8	18·08	Fair	H
" ..	1312	"	" 27.	Feb. 3	8 21	37	0 05 W	2 2 -2 2	" .	—16·5	—17·5	— 7·7	— 7·9	·0013	72·4	10·8	18 08	Good .	H
" ..	1317	"	" 27.	" 8	8 00	30	0 10 W.	1½ 1½ 1½ 1½	" .	—16·8	—17·0	—10 0	—10 0	·0013	72·4	10·8	18 08	Fair .	P
" ..	1319	"	" 27.	" 8	11 15	30	3 20 W.	1½ 1½ 1½ 1½	" .	—17 8	—17·5	—10·2	10·2	·0013	72·4	10·8	18·08	" ...	P
" ..	1321	"	" 27.	" 17	7 49	32	0 25 W.	2 2 2 2	" .	— 8·5	—12·0	— 2·0	— 2·0	·0013	72·4	10·8	18·1	Good. ..	H
" ..	1333	"	" 27.	" 18	7 15	30	0 05 E.	1½ 1½-1½-1½	" .	— 8·0	—10·0	— 3·0	— 3·0	·0013	72·5	10·8	18 1	Fair	P
" ..	1334	"	" 27.	" 20	8 07	35	1 00 W.	1½ 1½ 1½ 1½	" .	— 6·5	— 7·0	— 1·0	— 1·1	·0015	72·5	10·8	18·1	Good....	P

"	..	1336	"	"	27.	"	21	11	00	45	3	55 W.	2	-2	-2	-2	"	.	— 3·6	— 4·0	+ 0·6	+ 0·6	·0013	72·5	10·8	18·1	Poor......	P
"	..	1344	"	"	27.	"	22	6	58	33	0	05 E..	2	-2	-2	-2	"	.	— 10·3	—10·8	— 1·8	— 1·8	·0013	72·5	10·8	18·1	Good. ...	P
"	..	1347	"	"	27.	"	22	11	26	36	4	25 W.	2	-2	-2	-2	"	.	—13·3	— 13·5	— 4·5	— 4·6	·0013	72·5	10·8	18·24	Fair .. .	P
"	..	1349	"	"	27.	"	24	7	45	35	0	50 W.	2	-2	-2	-2	"	.	—10·0	— 10·0	— 2·0	— 2·0	·0013	72·5	10·8	18·24	Good. ...	P
"	..	1376	"	"	27.	Mar.	4	10	26	44	4	11 W	1	-1	-1	-1	"	.	— 6·5	— 7·5	+ 0·6	+ 0·3	·0013	72·4	10·8	18·25	Fair	H
"	..	1384	"	"	27.	"	9	10	22	85	4	30 W	1	-1	-1	-1	"	.	— 8·0	— 9·5	0·4	0·3	·0013	72·4	10·8	18·3	Hazy. ...	P
"	.	1395	"	"	27.	"	16	7	15	40	1	45 W.	1	-1	-1	-1	"	.	— 4·6	— 5·8	2·5	2·4	·0014	72·5	10·8	18·35	Fair	P

ψ ORIONIS 1138.

1907. Nov. 11.
G. M. T. 20ʰ 04ᵐ

Observed by } W. E. HARPER.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0155	− ·0057				1	48·3420		48·3356	·0249	26·89
1½	72·8845		72·8783	·0135	+19·59	2	45·2818	− ·0082			
2	72·4527	− ·0078				1	45·2802		45·2720	·0333	34·76
2	54·7465	− ·0046				1	27·4810		27·4570	·0351	30·47
2	53·4387		53·4313	·0200	33·15	2	27·2711	− ·0245			
2	53·1201	·0081				½	15·5256		15·4896	·0163	+12·62
2	48·7761	·0061				2	15·4345	− ·0359			

Weighted mean. . . .	+27·73	
V_a	+14·26	
V_d		09
Curvature		·28
Radial velocity	−41·6	

ψ ORIONIS 1138.*

1907. Nov. 11.
G. M. T. 20ʰ 04ᵐ

Observed by W. E. HARPER.
Measured by J. S. PLASKETT.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0062	+ ·0036				2	45·2712	+ ·0024			
½	72·8721		72·8766	·0118	+ 17·12	½	30·9215		30·9020	·0264	+ 23·71
2	72·4388	+ ·0061				½	30·8904	− ·0200			
2	54·0186	+ ·0102				½	29·0220		29·0025	·0013	− 1·15
2	53·4330		53·4420	·0397	45·40	½	27·4666		27·4478	·0259	+ 22·48
2	53·1052	+ ·0068				2	27·2652	− ·0186			
2	48·7672	+ ·0028				¼	20·8105		20·7840	·0034	+ 2·77
½	48·3138		48·3166	·0059	6·37	2	20·5475	− ·0275			
1½	45·2631		45·2655	·0268	27·97						

Weighted mean.	+ 28·00	
V_a	+ 14·26	
V_d		·09
Curvature.		·28
Radial velocity.	+ 41·9	

Check measurement

Ψ ORIONIS 1158.

1907. Nov. 23.
G. M. T. 17h 12m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0935	·0837	....	...	.....	2	53·1287	− ·0167	...	..	....
1	72·8452	.....	72·7622	·1026	−148·87	1	48·1357	....	48·1378	·1729	186·73
2	72·5259	·0810	....	....	....	2	45·2595	+ ·0141	....	..	....
2	54·7590	- ·0171	......	.	....	½	27·1693	....	27·2419	·1800	−156·24
1½	53·3004	....	53·2837	·1186	−135·56	2	27·1740	+ ·0726	....	.....	....

Weighted mean .... −154·26
V_a .... + 8·98
V_d .... + ·09
Curvature .... − ·28

Radial velocity .... − 145·5

Ψ ORIONIS 1182.

1907. Dec. 4.
G. M. T. 19h 46m

Observed by } J. S. PLASKETT.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
1	73·0102	− ·0004	....	......	....	2	43·5184	+ ·0200	....	.	....
1½	72·9704	....	72·9700	·1052	+152·67	¼	30·9904	....	31·0084	·1328	119·28
½	72·4474	− ·0025	....	......	....	2	30·8528	+ ·0176	......	..	....
1	54·0062	+ ·0226	....	......	....	½	29·1107	....	29·1300	·1262	111·26
½	53·4920	....	53·5110	·1087	124·84	¼	27·4963	....	27·5233	·1014	88·00
1½	53·0934	+ ·0186	....	......	....	2	27·2191	+ ·0275	....	.	....
2	48·7518	+ ·0182	....	...	....	¼	20·8518	......	20·8868	·1062	86·42
1	48·4296	....	48·4481	·1374	148·35	2	20·4846	+ ·0354	....	......	....
1½	45·3413	....	45·3633	·1246	130·05	¼	15·5887	......	15·6317	·1584	+122·65
2	45·2506	+ ·0230	....	.....	....	2	15·3552	+ ·0434	....	...	....

Weighted mean .... +132·51
V_a .... + 3·80
V_d .... − ·20
Curvature .... ·28

Radial velocity .... +135·8

Ψ ORIONIS 1183.

1907. Dec. 4.
G. M. T. 20ʰ 34ᵐ

Observed by } J. S. PLASKETT.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·3327	− ·0477	......	..	......	2	45·2646	+ ·0090	....	...	....
1	73·0361	− 0263	......	.	......	2	43·5247	+ ·0137	....	...	....
2	72·9944	....	72·9674	·1026	+148·89	½	31·0044	....	31·0144	·1388	124·67
½	72·4727	− 0278	....	..	....	2	30·8607	+ ·0097	....	....	....
1	54·0262	+ ·0026	....	..	....	1	27 5337	....	27·5487	·1268	110·05
½	53·5210	....	53·5140	1117	127·74	2	27·2311	+ ·0155	....	......	......
2	53·1204	- ·0084	....	..	....	1	20·8980	....	20·9180	·1374	111·82
3	48 7672	+ ·0028	......	..	....	2	20·4904	+ ·0206	....	.	....
¾	48·4416	.... .	48 4434	·1327	143·28	½	15 6127	....	15·6367	·1634	126·52
1	45·3760	....	45·3845	·1458	152·17	2	15·3742	+ 0244	.....		....

Weighted mean ... +135·80
V_a .... + 3·80
V_d .... ·23
Curvature........ ·28

Radial velocity....... +139·1

Ψ ORIONIS 1195.

1907. Dec. 28.
G. M. T. 16ʰ 00ᵐ

Observed by } J. S. PLASKETT
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73 0520	0422	.....	.	......	1	45 2050	....	45·2250	·0137	14·30
1	72·8655	...	72·8245	0403	−58·48	2	30·8315	− ·0389	....	...	....
2	72 4830	- 0381	. ..	.	....	¼	28·8849	....	28·9280	0758	66·82
1	54·0332	0044	....		...	¼	27 3468	......	27·3928	·0289	25·08
½	53·3871	...	53·3830	0193	22·07	2	27 2001	+ ·0465	....	..	......
1	53·1160	- 0040	....	.	...	½	20·7070	......	20·7630	·0176	14·32
2	48·7578	- 0122	...	.	..	2	20·4638	+ ·0562	....	....	....
½	48·2558	...	48·2690	0407	45·02	¼	15 3461	....	15 4145	·0588	−45·53
2	45 2538	- 0198	..	..	......	2	15 3299	+ ·0687	....	....	....

Weighted mean...... − 31·79
V_a .... − 8·07
V_d .... 0·0
Curvature.... − ·28

Radial velocity...... − 43·1

ψ ORIONIS 1195*

1907. Dec. 28.
G. M. T. 16ʰ 00ᵐ

Observed by / Measured by } J. S. Plaskett.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0135	− ·0037	....	....	....	2	48·7258	+ ·0442	....	...	....
1	72·8230	....	72·8195	·0453	−65·74	¼	48·2094	....	48·2540	·0567	61·22
2	72·4482	− ·0033	....	.....	....	..	45·2185	+ ·0551	....	.....	....
¼	66·1545	....	66·1640	·0239	31·84	2	45·1562	....	45·2110	·0277	28·91
2	54·7088	+ ·0331	....	..	....	½	20·6678	....	20·7578	·0288	18·55
2	53·9958	+ ·0330	....	....	....	2	20·4280	+ ·0920	....	...	....
½	53·3452	....	53·3800	·0223	25·50	¼	15·3196	....	15·4296	·0437	−33·84
1½	53·0748	+ ·0372	....	....	....	2	15·2876	+ ·1110	....	.....	....

Weighted mean	−	39·75
V_a	−	8·07
V_d		0·0
Curvature	−	·28
Radial velocity	−	47·9

* Check Measurement.

ψ ORIONIS 1196.

1907. Dec. 28.
G. M. T. 16ʰ 45ᵐ

Observed by / Measured by } J. S. Plaskett.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0046	+ ·0042	....	.....	....	1	45·1257	....	45·1872	·0515	53·75
½	72·8427	....	72·8475	·0173	− 25·11	2	30·7901	+ ·0803	....	....	....
2	72·4390	+ ·0059	....	......	....	¼	28·8261	....	28·9110	·0928	81·80
2	53·9884	+ ·0404	......	.	......	½	27·2504	....	27·3390	·0829	71·94
¼	53·2702	....	53·3117	·0906	103·62	2	27·1577	+ ·0889	....	.....	....
2	53·0700	+ ·0420	....	.....	....	¼	20·6274	......	20·7200	·0606	49·32
2	48·7150	+ ·0550	....	...	....	2	20·4270	+ ·0930	....	......	....
½	48·1743	....	48·2305	·0802	86·59	¼	15·2944	....	15·4015	·0718	−55·59
2	45·2122	+ ·0614	......	.	....	2	15·2908	+ ·1078	......	...	....

Weighted mean	−	62·33
V_a	−	8·08
V_d	−	·07
Curvature		·28
Radial velocity		70·8

ψ ORIONIS 1208.

1908. Jan. 1.
G. M. T. 20h 00m

Observed by / Measured by } J. S. Plaskett.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0428	— ·0330				2	45·2641	+ ·0095			
½	72·9980		72·9660	·1012	+146·86	2	30·8526	+ ·0178			
1½	72·4727	— ·0278				¼	29·1834		29·2085	·1984	174·91
1	54·0354	— ·0066				¼	27·6044		27·6344	·2125	184·43
½	53·5534		53·5494	·1471	168·22	2	27·2160	+ ·0306			
2	53·1133	— ·0013				¼	20·9432		20·9760	·1954	159·02
2	48·7654	+ ·0046				2	20·4873	+ ·0327			
1	48·4543		48·4593	·1486	160·44	¼	15·6603		15·7020	·2287	+177·08
1	45·3584		45·3678	·1291	134·74	2	15·3578	+ ·0418			

Weighted mean . . . +156·39
V_a . . . . —9·99
V_d . . . . — ·02
Curvature . . . . — ·28

Radial velocity . . . . . +145·9

ψ ORIONIS 1209.

1908. Jan. 1.
G. M. T. 19h 00m

Observed by / Measured by } J. S. Plaskett.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0522	— ·0424				2	45·2[illegible]38	+ ·0098			
½	73·0320		72·9890	·1242	+180·24	2	30·8434	+ ·0260			
2	72·4900	— ·0441				¼	29·1760		29·2070	·2032	179·06
2	54·0314	— ·0026				½	27·5338		27·5708	·1489	129·23
½	53·5572		53·5557	·1534	174·43	2	27·2094	+ ·0372			
2	53·1117	— ·0003				¼	20·8970		20·9410	·1604	130·53
2	48·7632	+ ·0068				2	20·4760	+ ·0440			
¼	48·4613		48·4690	·1683	181·71	¼	15·6247		15·6727	·1994	+154·39
1	45·3738		45·3836	·1449	151·23	2	15·3474	+ ·0488			

Weighted mean . . . +158·46
V_a . . . . 10·00
V_d . . . . — ·22
Curvature . . . . — 28

Radial velocity . . . . +148·0

ψ ORIONIS 1214.

1908. Jan. 3.
G. M. T. 15h 21m

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
3	73·0580	− ·0482	...	...	...	1	45·2463	...	45·2460	·0073	+ 7·62
½	72·9394	...	72·8990	·0242	+35·12	2	30·8538	+ ·0166	...	...	...
2	72·4976	·0527	...	...	...	¼	28·9764	...	28·9980	·0058	− 5·11
1½	54·0454	− ·0166	...	...	...	¼	27·3824	...	27·4084	·0135	−11·72
½	53·4241	...	53·4091	·0068	+ 7·78	2	27·2204	+ ·0262	...	...	...
2	53·1257	− ·0137	...	...	...	½	20·7356	...	20·7700	·0106	− 8·63
2	48·7757	− ·0057	...	...	...	2	20·4850	+ ·0350	...	...	...
¼	48·3130	...	48·3080	·0027	− 2·92	¼	15·3994	...	15·4460	·0273	−21·14
2	45·2740	− ·0004	...	...	...	1	15·3517	+ ·0469	...	...	...

Weighted mean	+ 4·15	
V_a		−10·86
V_d	+ ·02	
Curvature		− ·28
Radial velocity		− 7·0

ψ ORIONIS 1215.

1908. Jan. 3.
G. M. T. 16h 01m

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0242	− ·0144	...	...	...	¼	30·8730	...	30·9164	·0408	+36·64
1	72·8754	...	72·8615	·0033	− 4·79	1½	30·8270	+ ·0434	...	...	...
2	72·4571	− ·0122	...	...	...	¼	28·9427	...	28·9906	·0138	−12·16
2	54·0183	+ ·0105	...	...	...	½	27·3824	...	27·4330	·0111	+ 9·63
½	53·4276	...	53·4419	·0396	+45·26	2	27·1953	+ ·0513	...	...	...
1½	53·0957	+ ·0163	...	...	...	½	20·7092	...	20·7682	·0124	−10·09
2	48·7494	+ ·0296	...	...	...	2	20·4606	+ ·0594	...	...	...
¼	48·3062	...	48·3262	·0155	+16·74	¼	15·3897	...	15·4577	·0156	−12·07
2	45·2476	+ ·0260	...	...	...	1	15·3298	+ ·0688	...	...	...
1	45·2154	...	45·2414	·0027	+ 2·82						

Weighted mean	+ 6·16	
V_a		−10·86
V_d		− ·04
Curvature		− ·28
Radial velocity		− 5·0

Ψ ORIONIS 1220.

1908. Jan. 13
G. M. T. 17^h 26^m

Observed by } J. S. PLASKETT.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0460	− ·0362	......	....	......	2	45·2724	+ ·0012	....	..	......
½	72·9140	......	72·8787	·0138	+20·32	½	45·2480	......	45·2500	·0113	11·79
2	72·4802	·0341	......	......	......	1½	30·8588	+ ·0116	......	..	......
1½	54·0471	·0183	......	......	......	¼	28·9800	....	28·9946	·0092	8·11
½	53·4106	...	53·3980	·0043	4·92	½	27·3846	....	27·4016	·0203	17·62
1½	53·1214	·0094	...	....	......	2	27·2291	+ ·0175	......	....	....
2	48·7724	− ·0024	......	...	......	1	20·7507	......	20·7700	·0106	+8·63
¼	48·3066	....	48·3046	·0061	6·59	2	20·5002	+ ·0198	......	..	......

Weighted mean........	+10·24
V_a..................	−15·31
V_d................	− ·19
Curvature...........	− ·28
Radial velocity.........	5·5

Ψ ORIONIS 1221.

1908. Jan. 13.
G. M. T. 18^h 00^m

Observed by J. S. PLASKETT.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0077	+ ·0021	.	..	....	½	48·2640	...	48·3032	·0075	− 8·10
1	72·8428		72·8446	·0202	−29·31	½	45·2202	...	45·2632	·0245	+25·58
2	72·4437	− ·0012	....	....	..	2	45·2306	+ ·0430	......	....	......
2	54·7101	+ ·0318		..	....	¼	27·3822	....	27·4386	·0167	+14·50
2	53·3822	...	53·4142	·0119	+13·60	2	27·1900	+ ·0566	..	......	......
2	53·0800	+ ·0320	.....		.	2	20·6969	....	20·7580	·0226	−18·40
2	48·7314	+ ·0386	... ..		.	2	20·4587	+ ·0613	...	......	...

Weighted mean..........	+4·25
V_a..................	−15·31
V_d................	− ·22
Curvature............	− ·28
Radial velocity..........	11·6

ψ ORIONIS 1227.

1908. Jan. 14.
G. M. T. 13h 21m

Observed by } J. S. PLASKETT.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity
2	73·0150	- ·0052	...	...	...	2	45 2726	+ ·0010	...	...	...
¼	72·9972	...	72·9900	·1252	+181·69	½	31·0876	...	31·0810	·2044	183·59
1½	72·4545	– ·0096	...	...	...	2	30 8775	0071	...	...	...
1	54·0252	+ ·0036	...	...	...	¼	29 1706	...	29 1650	·1612	142·07
½	53·5358	...	53·5360	·1337	152·90	¼	27 5845	...	27 5800	1581	137·22
2	53·1120	...	...	...	...	2	27·2498	·0032	...	...	...
2	48 7702	– ·0002	...	...	...	¼	20·9600	...	20·9500	·1694	+137·85
¼	48·4710	...	48·4710	·1603	173·08	2	20 5298	– ·0098	...	...	...
¼	45·3752	.	45·3760	·1373	143·30						

Weighted mean .... +156·23
V_a .... –15·64
V_d .... + ·15
Curvature .... – ·28

Radial velocity. .. .. +140·5

ψ ORIONIS 1227.*

1908. Jan. 14.
G. M. T. 13h 21m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0188	– ·0090	...	...	...	1	48·4800	...	48·4770	1663	179·60
½	72·9643	...	72·9542	·0894	+129·72	2	45·4040	...	45·3997	1610	168·08
2	72·4582	– ·0133	...	...	...	2	45·2780	–0044	...	...	...
2	54·0325	– ·0037	...	...	...	½	27·6012	...	27·5974	1755	152·33
1½	53·5490	...	53·5436	·1413	161·50	2	27·2504	–0038	...	...	...
2	53·1170	– ·0050	...	...	...	1	20·9720	...	20 9613	1807	+147·08
2	48·7724	– ·0024	...	...	...	2	20 5311	–0111	...	...	...

Weighted mean...... +160·94
V_a .... –15·64
V_d ....+ ·15
Curvature .... – ·28

Radial velocity........ +145·2

* Check measurement.

ψ ORIONIS 1233.

1908. Jan. 16.
G. M. T. $11^h 55^m$

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0133	− ·0035	...	...	...	½	45·3102	...	45·3155	·0768	80·16
½	72·9294	...	72·9240	·0592	+ 85·91	2	45·2684	+ ·0052	...	...	...
2	72·4524	− ·0075	...	...	...	¼	30·9514	...	30·9474	·0718	64·49
2	54·0273	+ ·0015	...	...	...	2	30·8744	− ·0040	...	...	...
½	53·4464	...	53·4520	·0497	56·83	¼	29·0574	...	29·0540	·0502	44·24
2	53·1053	+ ·0067	...	...	...	¼	27·4774	...	27·4744	·0525	+ 45·56
2	48·7630	+ ·0070	...	...	...	2	27·2494	− ·0028	...	...	...
¼	48·3717	...	48·3785	·0678	73·20						

Weighted mean	+ 67·33	
V_a		− 16·28
V_d	+ ·21	
Curvature		− ·28
Radial velocity	+ 51·0	

ψ ORIONIS 1238.

1908. Jan. 20.
G. M. T. $12^h 57^m$

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	72·9824	+ ·0274	...	...	...	2	45·2571	+ ·0165	...	...	...
¼	72·7857	...	72·8097	·0551	− 79·96	½	45·1368	...	45·1530	·0857	89·44
2	72·4242	+ ·0207	...	...	...	1	30·8592	+ ·0112	...	...	...
2	54·0122	+ ·0166	...	...	...	¼	30·7522	...	30·7650	·0906	81·38
1	53·2817	...	53·2982	·1041	119·04	½	27·2694	...	27·2824	·1395	121·07
2	53·0957	+ ·0163	...	...	...	2	27·2326	+ ·0140	...	...	...
2	48·7532	+ ·0168	...	...	...	½	20·6574	...	20·6680	·1126	− 91·63
¼	48·2384	...	48·2549	·0558	60·25	2	20·5096	+ ·0104	...	...	...

Weighted mean		− 96·30
V_a		− 18·03
V_d	+ 0·12	
Curvature		− 0·28
Radial velocity		−114·5

ψ ORIONIS 1239.

908. Jan. 20.
G. M. T. 13^h 53^m

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity
2	72·9948	+ ·0150	...		...	2	45·2593	+ ·0143	...	...	...
½	72·7832	...	72·7972	·0676	— 98·10	½	45·1530	...	45·1670	·0717	74·83
2	72·4322	+ ·0127	...		...	1	30·8690	+ ·0114	...	...	...
2	54·0140	+ ·0148	...	...	...	½	30·7664	...	30·7775	·0981	88·11
1	53·2777	...	53·2920	·1103	126·13	¼	27·3097	...	27·3110	·1109	96·25
2	53·0982	+ ·0138	...	...	...	2	27·2476	+ ·0010	...	...	...
2	48·7523	+ ·0177	...	...	...	¼	20·6404	...	20·6310	·1496	—121·74
½	48·2301	...	48·2450	·0657	70·94	1	20·5297	— ·0097	...	...	...

Weighted mean ....— 99·04
V_a.......................— 17·88
V_d............... + 0·04
Curvature.............. — 0·28

Radial velocity ....—117·2

ψ ORIONIS 1257.

1908. Jan. 22.
G. M. T. 15^h 29^m

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0294	— ·0196	...	...	...	½	48·3194	...	48·3320	·0213	23·00
¼	72·9192	...	72·8994	·0346	+ 50·21	½	45·2558	...	45·2710	·0323	33·71
2	72·4648	— ·0199	...	...	...	2	45·2582	+ ·0154	...	...	...
2	54·0246	+ ·0042	...	...	...	¼	27·4321	...	27·4620	·0401	34·80
1	53·4333	...	53·4383	·0360	41·17	2	27·2163	+ ·0303	...	...	...
2	53·1064	+ ·0056	...	...	...	½	20·7860	...	20·8210	·0404	+ 32·88
2	48·7577	+ ·0123	...	...	...	2	20·4850	+ ·0350	...	...	...

Weighted mean ....+ 35·74
V_a.......................— 18·82
V_d.......................— 0·10
Curvature...............— 0·28

Radial velocity.......... + 16·5

ζ ORIONIS 1264.

1908. Jan. 23.
G. M. T. 14^h 03^m

Observed by / Measured by } J. S. Plaskett.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity
2	73 0428	—·0330				2	48·7807	—·0107			
$\frac{1}{2}$	72 8747		8407	0240	—34·97	$\frac{1}{2}$	48·2864		2764	·0343	37·03
1	72 4818	–·0369				2	45·2757	— 0021			
2	54 0477	—·0189				$\frac{1}{2}$	45·1532		1510	0877	91·94
$\frac{1}{2}$	53 3306		3116	·0907	103 71	$\frac{1}{2}$	27·2624		2760	·1459	-126·63
2	53 1312	-·0192				2	27·2330	+·0136			

Weighted mean	–77·60
V_a	–19 16
V_d	00
Curvature	— ·28
Radial velocity	— 97·0

ζ ORIONIS 1264*

1908. Jan. 23.
G. M. T. 14^h 03^m

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73 0831	—·0733				$\frac{1}{2}$	48·3130		·2700	·0407	43·96
$\frac{1}{4}$	72·9085		8361	·0287	—41 64	2	45·3130	0394			
2	72·5140	0696				$\frac{1}{2}$	45 1863		·1470	0917	95·73
1	54·0815	0527				$\frac{1}{2}$	27 2977		·2769	1450	125·86
2	53 3680		3160	0863	98 53	2	27 2674	·0208			
2	53 1634	0514				$\frac{1}{2}$	20·7050		6900	0906	—73·75
2	48·8135	0435				2	20 5350	—·0150			

Weighted mean	85·19
V_a	-19·16
V_d	·00
Curvature	·28
Radial velocity	104·6

* Check measurement; –101·2 used as the combined result.

ψ ORIONIS 1271.

1908. Jan. 24.
G. M. T. 12ʰ 49ᵐ

Observed by } J. S. PLASKETT.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0210	− ·0112	...	...	...	¾	45·3960	...	45·3988	·1601	167 10
½	72·9833	...	72·9725	·1077	+156·29	2	45·2708	+ ·0028	...	...	...
2	72·4547	− ·0098	...	...	...	1½	30·8783	− ·0079	...	...	...
2	54·0336	− ·0048	...	...	...	¼	29·2073	...	29·1993	1955	172·29
½	53·5414	...	53·5372	·1349	154·26	½	27·6207	...	27·6127	·1908	165 59
2	53·1158	− ·0038	...	...	...	2	27·2547	− ·0081	...	...	...
2	48·7707	− ·0067	...	...	...	¼	20·9874	...	20·9745	·1939	157·80
1	48·4527	...	48·4520	·1413	152·56	2	20·5330	− ·0130	...	...	...

Weighted mean..........	+159·60	
V_a		− 19·51
V_d	+ 0·12	
Curvature		− 0·28
Radial velocity	+139·9	

ψ ORIONIS 1279.

1908. Jan. 27.
G. M. T. 11ʰ 42ᵐ

Observed by } J. S. PLASKETT.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0428	− ·0330	...	...	...	2	53·1182	− ·0062	...	...	...
½	72·9974	...	·9645	·0997	+144·68	2	48·7737	− ·0037	...	...	...
2	72·4776	− ·0327	...	...	...	½	48·4300	...	4265	·1158	125·03
2	54·0337	− ·0049	...	...	...	½	45·3697	...	3704	1317	+137·45
½	53·5493	...	·5438	·1415	161·80	2	45·2723	+ ·0008	...	...	...

Weighted mean		+ 142·24
V_a	20·53	
V_d		+ ·16
Curvature.. ..	− ·28	
Radial velocity		+ 121·6

ξ ORIONIS 1279.

1908. Jan. 27.
G. M. T. 11h 42m

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0561	− ·0463	......	.	......	3	48·7805	·0105	......	...	.....
¼	72·9960	....	·9500	·0852	+123·62	1	48·4267	....	·4170	1063	114·80
2	72·4898	− ·0449	......	......	....	2	45·3761	...	·3702	·1315	137·29
2	54·0399	− ·0111	......	..	.....	2	45·2795	0059	...	......	....
¾	53·5541	......	·5411	·1388	158·65	1	20·9382	.....	9422	·1616	·131·54
2	53·1258	− ·0138	....	.	.....	2	20·5159	+ 0041	......	......	......

Weighted mean.... ...... +134·16
V_a .... −20·53
V_d .... + ·16
Curvature........ − ·28

Radial velocity........ + 113 5

* Check measurement.

ψ ORIONIS 1283.

1908. Jan. 27.
G. M. T. 14h 21m

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0126	— ·0028	....	....	....	¼	45·2818	...	45·3080	·0693	72·28
½	72·9151	....	72·9124	·0477	+69·21	2	45·2470	+ ·0266	....	......	....
2	72·4474	— ·0025	....	....	...	2	30·8390	+ ·0314	....	......	....
2	54·0174	+ ·0114	....	..	...	¼	29·0084	....	29·0404	·0366	32·87
1	53·4616	....	53·4780	·0757	86·53	¼	27·4810	....	27·5135	·0916	+79·51
2	53·0943	+ ·0177	.....	.....	.....	2	27·2136	+ ·0330	......	......	......
2	48·7450	+ ·0250	....	....							

Weighted mean.......... +77·41
V_a................ −20·53
V_d .... — 0·04
Curvature .... — 0·28

Radial velocity .... + 56·6

ψ ORIONIS 1296.

1908. Jan. 29.
G. M. T. $11^h\ 00^m$

Observed by } J. S. PLASKETT.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0137	− ·0039	......	......	......	½	45·3717	......	45·3742	·1355	141·42
½	72·9910	......	72·9875	·1227	+178·06	2	45·2711	+ ·0025	......	......	......
2	72·4464	− ·0015	......	......	......	2	30·8767	− ·0063	......	......	......
2	54·0268	+ ·0020	......	......	......	¼	27·6107	......	27·6030	·1811	157·18
1	53·5652	......	53·5665	·1642	187.78	2	27·2544	− ·0078	......	......	......
2	53·1120	·0000	......	......	......	½	21·0003	......	20·9890	·2084	169·59
2	48·7682	+ ·0018	......	......	......	2	20·5314	− ·0114	......	......	......
1	48·4478	......	48·4496	·1389	149·97						

Weighted mean	+165·76	
V_a		−21·19
V_d	+ 0·21	
Curvature..........		− 0·28
Radial velocity.........	+144·5	

ψ ORIONIS 1301.

1908. Jan. 29.
G. M. T. $15^h\ 01^m$

Observed by W. E. HARPER.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	54·7317	+ ·0102	......	......	......	1	45·3617	......	45·3740	·1353	141·25
1½	53·5614	......	53·5703	·1680	+192·02	2	45·2612	+ ·0124	......	......	......
2	53 1037	+ ·0083	......	......	......	1	27·6252	......	27·6334	·2115	+183·58
2	48·7601	+ ·0099	......	......	......	2	27·2385	+ ·0081	......	......	......
3	48·4633	......	48·4734	·1627	175·72						

Weighted mean	+175·39
V_a	− 21·25
V_d	− 0·09
Curvature...	− 0·28
Radial velocity............ ...	+153·8

ζ ORIONIS 1311.

1908. Jan. 29.
G. M. T. 17^h 02^m

Observed by | Measured by | W. E. HARPER.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
1	54·0255	+ ·0033				2	45·2785	·0049			
1	53·5720		·5750	·1727	+197·40	½	27·7122		·6919	·1700	147·56
2	53·1099	+ ·0021				2	27·2667	·0201			
2	48·7711	− ·0011				1	21·0246		·0040	·2234	+181·85
½	48·4455		·4440	·1333	144·00	2	20·5406	·0206			
1	45·4049		·4000	·1613	163·40						

Weighted mean .... +173·36
V_a .... −21·27
V_d .... − ·22
Curvature .... ·28

Radial velocity .... +151·6

ζ ORIONIS 1312.

1908. Feb. 3.
G. M. T. 13^h 21^m

Observed by | Measured by | W. E. HARPER.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	72·9746	+ ·0352				1	48·4210		·4564	·1457	157·36
1	72·9598		·9943	·1295	+187·90	1½	45·3324		·3690	·1303	136·03
2	72·4125	·0324				2	45·2370	·0366			
1	66·2862		·3192	·1313	174·89	1	27·5753		·6019	·1800	156·24
2	53·9968	·0320				2	27·2205	·0261			
1½	53·5395		·5727	·1704	194·77	1	20·9745		·9941	·2135	+173·79
2	53·0783	·0337				2	20·5007	+ ·0193			
2	48·7345	·0355									

Weighted mean .... +168·30
V_a .... −22·77
V_d .... + ·06
Curvature .... − ·28

Radial velocity .... +145·3

ψ ORIONIS 1312*

1908. Feb. 3.
G. M. T. 13h 21m

Observed by / Measured by } W. E. Harper.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
	73·0406	– ·0308				1	48·4755		·4497	·1390	150·12
1	73·0220		·9900	·1252	+181·66	1½	45·4058		·3800	·1413	147·52
2	72·4805	·0356				2	45·2996	·0260			
2	54·0602	·0314				1	27·6385		·6019	·1800	156·24
1½	53·5920		·5628	·1605	183·45	2	27·2837	·0371			
2	53·1402	·0282				2	21·0312		·9860	·2054	+167·20
2	48·7957	·0257				2	20·5657	– ·0457			

Weighted mean		+164·86
V_a	– 22·77	
V_d		+ ·06
Curvature	– ·28	
Radial velocity		+141·9

* Accidentally remeasured without knowledge of previous work.

ψ ORIONIS 1317.

1908. Feb. 8.
G. M. T. 13h

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0117	– ·0017				2	48·4652		·4598	·1491	161·03
1	72·9768		·9749	·1101	+159·75	½	45·3524		·3435	·1048	109·41
2	72·4499	·0050				2	45·2826	·0090			
2	54·7454	·0035				½	27·6069		·5803	·1584	137·49
1	53·5262		·5184	·1161	132·70	2	27·2735	·0269			
2	53·1212	·0092				½	20·9957		·9591	·1785	+145·30
2	48·7751	·0051				2	20·5573	– ·0373			

Weighted mean		+ 147·39
V_a	– 24·16	
V_d	·00	
Curvature	– ·28	
Radial velocity		+ 121·0

ψ ORIONIS 1317.*

1908. Feb. 8.
G. M. T. 13^h

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0090	+ ·0008	....	.....	....	½	45·4078	... ...	·4027	·1640	171·22
1	72·9720	....	·9722	·1074	+155·84	2	45·2787	− 0051	.... ..	.....	....
2	72·4467	− ·0018	....	.....	....	2	27·6052	....	·5819	1600	138·88
1	66·3180	....	·3142	·1263	168·23	2	27·2701	− ·0235	....	....	....
2	54·0357	− 0077	....	.....	....	½	20.9931	.. ..	·9631	1825	148·55
1½	53·5385	. ...	·5316	·1293	147·80	2	20·5504	− .0304	....	.....	....
2	53 1177	− ·0057	... .	....	....	½	15·7080	....	·6710	·1977	+153·02
2	48·7736	− 0036	....	...	.. ..	2	15·4362	− ·0376	....	......	....
2	48·4612	.. ..	·4574	·1467	158·44						

Weighted mean................ +152·98
V_a.............. − 24·16
V_d........ .. .. ·00
Curvature. ...... − ·28

Radial velocity .... +128·5

* Check measurement.

ψ ORIONIS 1319.

1908. Feb. 8.
G. M. T. 16^h 15^m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0146	− ·0048	....	.. ...	..... .	1½	45·4050	. ...	·3886	·1500	156·60
¼	72·9507	....	·9458	·0810	+117·55	2	45·2900	·0164	.. ....	.....	....
¼	53·5788	....	·5674	·1651	188·70	¼	31·1235	.. ...	·0790	·2034	182·65
1½	54·0414	·0126	....	. ..	....	1	30·9152	0448	....	......	....
1½	53·1229	0109	. ...	...	....	½	27 2975	0509	.... .	.. ..	.. .. .
2	48·7802	·0102	....	......	....	1½	21 0620	....	·0014	·2208	+179·75
½	48·4555	....	·4444	·1337	144·40	2	20·5810	− 0610	....	.. ..	....

Weighted mean...... ... . +165·20
V_a .... − 24·16
V_d ... . ·22
Curvature 28

Radial velocity.... .... +140·5

ψ ORIONIS 1321.

1908. Feb. 17.
G. M. T. $12^h 49^m$

Observed by W. E. Harper.
Measured by J. S. Plaskett.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0456	—·0358	...	...	...	½	48·2361	...	·2116	·0991	107·00
¼	72·8334	...	·7994	·0654	—94·91	2	45·2982	·0246	...	...	...
2	72·4761	·0312	...	...	...	½	45·1677	...	·1427	·0960	100·20
¼	66·1178	...	·0878	·1000	133·24	½	30·7772	...	·7472	·1284	115·33
2	54·0792	·0304	...	...	...	2	30·9007	·0303	...	...	...
½	53·3260	...	·3000	·1023	116·98	¼	28·8860	...	·8560	·1478	130·25
2	53·1367	·0247	...	...	...	¼	27·3020	...	·2718	·1501	—130·27
2	48·7936	·0236	...	...	...	2	27·2770	—·0304	...	...	...

Weighted mean...	—113·97
V_a	—26·10
V_d	·01
Curvature.	— ·28
Radial velocity..........	—140·4

ψ ORIONIS 1333.

1908. Feb. 18.
G. M. T. $12^h 15^m$

Observed by } J. S. Plaskett.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0358	—·0260	...	...	...	2	48·7752	·0052	...	...	...
½	72·9900	...	·9635	·0987	+143·23	1	48·4496	...	·4440	·1333	143·92
2	72·4724	·0275	...	...	...	½	45·3684	...	·3630	·1243	129·73
¼	66·3020	...	2830	0941	125·38	2	45·2798	·0062	...	...	...
2	54·7507	·0088	...	...	...	¼	30·9882	...	·9840	·1084	+97·36
1	53 5193	...	·5075	·1052	120·30	1	30·8747	—·0043	...	...	...
2	53·1247	0127	...	...	...						

Weighted mean	+130·40
V_a ....—26·28	
V_d	+ ·03
Curvature. ....— ·28	
Radial velocity..	+103·9

ζ ORIONIS 1334.

1908. Feb. 20.
G. M. T. 13h 07m

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0206	− ·0108				1	45·2014		2135	0252	26·31
1	72·8584		.8470	0178	−25·83	½	27·3656		·3815	0404	35 07
2	72·4583	− ·0134				2	27·2309	+ ·0159			
2	54·7360	− 0059				½	20·7429		·7610	·0196	15·95
1½	53·3892		3944	0079	9·03	2	20·5018	+ ·0182			
2	53·1070	+ ·0050				½	15 3990		4238	·0495	− 38 31
2	45·2615	+ ·0121				2	15·3738	+ 0248			

Weighted mean	−22·07
V_a	−26·62
V_d	− ·06
Curvature	− ·28
Radial velocity	−49·0

ζ ORIONIS 1336.

1908. Feb. 21.
G. M. T. 16h 07m

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	54·7184	+ ·0235				2	45·2406	0330			
1	53·5039		5278	1255	+143·45	½	27 5000		·5343	·1224	106·24
2	53·0880	0240				2	27·2021	·0445			
2	48·7411	0289				½	20 8572		·9031	·1225	+ 99·72
½	48·4273		·4565	1458	157·46	2	20·4740	+ ·0460			
½	45 3162		3492	1105	115·36						

Weighted mean		− 130·67
V_a	− 26·79	
V_d	− ·25	
Curvature	− ·28	
Radial velocity		103·3

ψ ORIONIS 1344.

1908. Feb. 22.
G. M. T. 11h 58m

Observed by J. S. PLASKETT.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity
2	73·0059	+0039				½	48·1852		·2155	·0952	102·82
¼	72·7533		7894	·0754	109·40	2	45·2398	0338			
2	72·4403	0041				2	45·0852		·1191	1196	124·86
2	54·7151	·0268				¼	27·2974		·3376	·0843	73 17
2	53·2911		·3153	·0870	99·44	2	27·2064	·0402			
2	53·0882	·0238				1	20·6002		·6436	1370	−111·52
2	48·7404	·0296				2	20·4766	+ ·0434			

Weighted mean	−109·53
V_a	− 26·96
V_d	+ ·03
Curvature	− ·28
Radial velocity	136·7

ψ ORIONIS 1347.

1908. Feb. 22
G. M. T. 16h 26m

Observed by J. S. PLASKETT.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	72·9771	+·0327				1	48·1722		·2128	·0979	105·73
¼	72·7638		·7961	·0687	−99·68	2	45·2352	·0384			
2	72·4141	·0303				½	45 0961		·1345	·1042	108·78
2	54·7032	·0387				¼	27·3226		·3481	·0738	64·06
1	53·2634		·2987	·1030	117·73	2	27 2211	·0255			
2	53·0771	·0349				½	20·6205		·6388	·1418	−115·42
2	48·7291	·0409				2	20·5018				

Weighted mean	−107·57
V_a	− 26·96
V_d	− ·28
Curvature	− ·28
Radial velocity	135·1

ψ ORIONIS 1349

1908. Feb. 24.
G. M. T. 12ʰ 45ᵐ

Observed by } J. S. PLASKETT.
Measured by }

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	72·9994	+ ·0104				1	45·3180		·3015	·0628	65·54
1	72·9154		·9064	·0416	+ 60·37	2	45·2904	— ·0168			
2	72·4374	+ ·0075				2	30·9227	— ·0523			
2	54·7462	— ·0043				½	29·1100		·0560	·0522	46·89
2	53·4604		·4544	·0521	59·58	½	27·5552		·5000	·0781	67·78
2	53·1197	— ·0077				2	27·3024	— ·0558			
2	48·7840	— ·0140				1	20·8993		·8280	·0474	+ 38·57
1½	48·3830		·3685	·0678	73·20	2	20·5928	— ·0728			

Weighted mean		+ 60·10
V_a	— 27·18	
V_d	— ·04	
Curvature	— ·28	
Radial velocity		+ 32·6

ψ ORIONIS 1349*

1908. Feb. 24.
G. M. T. 12ʰ 45ᵐ

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	73·0220	— ·0122				2	48·3977		·3575	·0468	50·54
1	72·9433		·9305	·0657	+ 95·33	1½	45·3455		·3031	·0644	67·23
2	72·4596	·0147				2	45·3160	·0424			
2	54·0643	·0355				1	27·5722		·5294	·1075	93·31
2	53·4775		·4445	·0422	48·23	2	27·3249	·0783			
2	53·1442	·0322				1	20·9237		·8450	·0644	+ 52·42
2	48·8099	·0399				2	20·6157	— ·0957			

Weighted mean		+ 63·46
V_a	— 27·18	
V_d	— ·04	
Curvature	— ·28	
Radial velocity		+ 36·0

* Check measurement.

ψ ORIONIS 1376.

1908. March 4.
G. M. T. $15^h\ 26^m$

Observed by W. E. Harper.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	54·7343	+ ·0076	....	....	....	1½	48·4337	....	4541	·1434	154·87
1	54·5090	....	·5198	·1175	+134·30	2	45·3374	....	·3622	·1235	+128·93
2	53·1001	·0119	....	.. ..	....	2	45·2487	+ 0249	....	......	. ...
2	48·7498	·0202	....	.. ...	....						

Weighted mean .... +138·77
V_a .... −27·98
V_d .... − ·27
Curvature.......... − ·28

Radial velocity................ +110·2

ψ ORIONIS 1384.

1908. March 9.
G. M. T. $15^h\ 22^m$

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
½	53·4557	....	·4587	·0562	+ 64·24	2	45·2547	·0189	....	......	. ...
2	54·7418	+ ·0001	....	. ...	....	2	27·4936	....	·5471	·1252	108·67
2	53·1086	·0034	....	......	... .	2	27·1925	·0541	....	......	....
2	48·7565	·0135	....	.....	....	½	20·8501	....	·9141	·1335	+108·67
½	48·4457	....	·4597	·1490	160·92	2	20·4554	+ ·0647	....	....	......

Weighted mean ....+109·79
V_a .... −27·97
V_d .... − ·27
Curvature.......... − ·28

Radial velocity....... .. . .+ 81·3

ψ ORIONIS 1384

1908. March 9.
G. M. T. 15^h 22^m

Observed by | J. S. Plaskett.
Measured by | J. S. Plaskett.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
2	54·8030	·0611*	....	....	....	½	20·8868	....	·8945	·1139	92·69
1	53·5455	....	·4925	·0902	+103·15	2	20·5124	+ ·0076	....	....	....
2	54·0878	− ·0590	....	....	....	2	27·2518	− ·0052	....	....	....
2	53·1629	− ·0509	....	....	....	½	29 1755	....	1655	·1617	142·51
2	48 8128	− ·0428	....	....	....	2	30·8859	− ·0155	....	....	....
1½	48·4992	....	4585	·1478	159 58	¼	31·0356	....	·0200	·1444	+129·70

Weighted mean		+ 131·35
V_a	− 27 97	
V_d	·27	
Curvature	·28	
Radial velocity		102 8

*Check measurement

ψ ORIONIS 1395.

1908. March 16.
G. M. T. 12^h 15^m

Observed by J. S. Plaskett.
Measured by C. R. Westland.

Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.	Wt.	Mean of Settings.	Correction to Compar. Lines.	Corrected Star Setting.	Displac. in Revol.	Velocity.
1	72·9770	+ ·0328	....	....	....	2	45·2465	+ ·0271	....	....	....
½	72·7200	....	·7501	1147	116·43	½	45·1263	....	·1533	·0854	89·16
1	72·4060	+ ·0389	....	....	....	2	30·8608	+ ·0096	....	....	....
2	54·7085	+ ·0334	....	....	....	½	30 8066	....	·8161	·0595	53·43
2	53 2627	....	·2902	·1121	128·13	½	27·3343	....	·3411	·0808	70·13
2	53 0852	+ ·0268	....	....	....	2	27·2399	+ ·0067	....	....	....
2	48 7433	+ ·0267	....	....	....	1	20·6681	....	6663	·1143	−93·04
½	48·1960	....	·2227	0886	95·04	2	20·5219	·0019	....	....	....

Weighted mean	−	106·62
V_a	−	27·96
V_d	−	·12
Curvature	−	·28
Radial velocity	−	135·0

ψ ORIONIS.

Summary of Measures.

Plate No.	Date.	Julian Date.	No. of Lines.	Velocity.	Measurer.	Weighted Mean.	Phase.	Residual C—O
	1907.							
1138	Nov. 11·83	2,417,891·83	6	+ 41·6	H			
			8	+ 41·9	P	+ 41·7	·56	+ 24·5
1158	Nov. 23·72	903·72	4	− 145·5	H		2·35	+ 1·5
1182	Dec. 4·82	914·82	9	+ 135·8	P		·82	3·5
1183	" 4·85	914·85	8	+ 139·1	P		·85	· 2·5
1195	" 28·67	938·67	8	43·1	P			
			7	− 47·9	P	45·5	1·94	20·0
1196	" 28·70	938·70	8	70·8	P		1·97	4·5
	1908.							
1208	Jan. 1·76	942·76	8	− 145·9	P		·97	+ 1·5
1209	" 1·79	942·79	8	+ 148·0	P		1·00	+ 1·2
1214	" 3·64	944·64	8	− 7·0	P		·33	− 1·3
1215	" 3·67	944·67	9	− 5·0	P		·36	− 7·5
1220	" 13·73	954·73	7	5·5	P		·32	− 15·0
1221	" 13·75	954·75	6	− 11·6	W		·34	+ 0·3
1227	" 14·56	955·56	8	− 140·5	P			
			6	− 145·2	H	143·0	1·15	+ 1·5
1233	" 16·50	975·50	7	+ 51·0	P		·56	+ 15·0
1238	" 20·54	961·54	7	− 114·5	P		2·07	+ 6·8
1239	" 20·58	961·58	7	− 117·2	P		2·11	+ 0·5
1257	" 22·65	963·65	6	+ 16·5	P		1·66	+ 19·0
1264	" 23·58	964·58	5	− 97·0	P			
			6	− 104·6	H	− 101·2	·06	− 4·0
1271	" 24·53	965·53	7	+ 139·9	P		1·01	+ 9·8
1279	" 27·49	968·49	4	+ 121·6	P			
			5	+ 113·5	H	116·2	1·44	15·5
1283	" 27·59	968·59	5	+ 56·6	P		1·54	+ 14·5
1296	" 29·46	970·46	6	+ 144·5	P		·89	3·5
1301	" 29·63	970·63	4	+ 153·8	W		1·06	− 4·0
1304	" 29·71	970·71	5	+ 151·6	H		1·14	6·0
1312	Feb. 3·56	975·56	7	+ 145·3	H			
			6	+ 141·9	H	+ 143·6	·94	+ 1·8
1317	" 8·54	980·54	6	+ 121·0	W			
			8	+ 128·5	H	+ 126·0	·86	+ 12·0
1319	" 8·68	980·68	6	+ 140·5	H		1·00	+ 9·5
1321	" 17·53	989·53	8	140·4	P		2·28	+ 0·5
1333	" 18·51	990·51	6	+ 103·9	P		·73	+ 10·0
1334	" 20·54	992·54	6	− 49·0	W		·24	− 1·0
1336	" 21·67	993·67	5	+ 103·3	W		1·36	+ 13·0
1344	" 22·50	994·50	6	− 136·7	W		2·19	+ 4·5
1347	" 22·69	994·69	6	135·1	W		2·38	6·0
1349	" 24·53	2,417,996·53	7	+ 32·6	P			
			6	+ 36·0	H	+ 34·3	1·70	− 13·5
1376	Mar. 4·64	2,418,005·64	3	+ 110·2	W		·70	− 0·6
1384	" 9·64	010·64	4	+ 81·3	W			
			5	+ 102·8	P	+ 95·6	·65	0·8
1395	" 16·51	017·51	7	− 135·0	W		2·47	+ 2·0

In the above summary of measures the phases are obtained from a period of 2·526 days, and an initial epoch, T_0, Dec. 4·0, 1907, or Julian Day 2,417,914·0. A plot of the observations is shown in Fig. 8. It is seen by this figure and the velocity curve there drawn, that very good agreement occurs near the points of maximum and minimum velocity but that the agreement is not so good along the ascending and descending branches. This may be partly explained, in the case of some of the observations, by their having been taken on nights partly cloudy where the middle of the observed time might easily not be the mean time of exposure, thus displacing the observation horizontally, and this displacement may be relatively large in a binary of as short a period as this. Quite large discrepancies may also be explained by the

diffuseness of the lines and the difficulty of setting. If the negative has been under-exposed, the lines are very broad and weak and the velocity resulting may easily, I should judge, be in error to the extent of 10 or 15 kilometres or even more in one or two cases.

Considering the character of the spectrum, the curve is very well defined, allowing the elements of the orbit to be closely determined. The large range, about 294 kms., diminishes the relative error considerably, while the close determinations of the maximum and minimum points are also of great assistance in limiting the elements.

As in ι Orionis and all other spectroscopic binary stars determined here, preliminary values were first obtained by your method and by that of Lehmann-Filhes from a smooth curve drawn through the observations. They give e as about 0·05 and 0·03 and ω as about 200°. A curve corresponding to these elements, which was obtained graphically by your method, showed that these values were not the best, and trials of varying eccentricities and longitudes of the apse were then made. The curve agreeing best with the observations is drawn in Fig. 8. This corresponds to an eccentricity of 0·063 and a longitude of the apse of 186°, which values can not be very far from the true ones, the eccentricity being determined to within less than 0·01 and ω to less than 5°.

By this method the phase of periastron passage is closely determined as 2·36 days and apastron as 1·10 days, while the remaining elements are readily determined by the usual formulæ. We have given

U = period	= 2·52509 days.
A = maximum positive velocity	= 150·4 km.
B = maximum negative velocity	= 144·0 "
K = half the amplitude	= 147·2 "
e = eccentricity	= 0·063
ω = longitude of the apse	=186°
T = time of periastron passage, Julian Day	= 2,417,916·36

and we obtain

$$\gamma = \text{velocity of the system}$$

$$= \frac{A-B}{2} - Ke\cos\omega \qquad = +\ 12\cdot4 \text{ km.}$$

$$a \sin i = 43200\frac{KU}{\pi}\sqrt{1-e^2} \qquad = 5{,}103{,}000 \text{ km.}$$

A diagram showing the proportions of the orbit is given in Fig. 9. A treatment of the residuals in the last column of the summary of velocities gives the probable error of a single observation as ± 7·7 km.

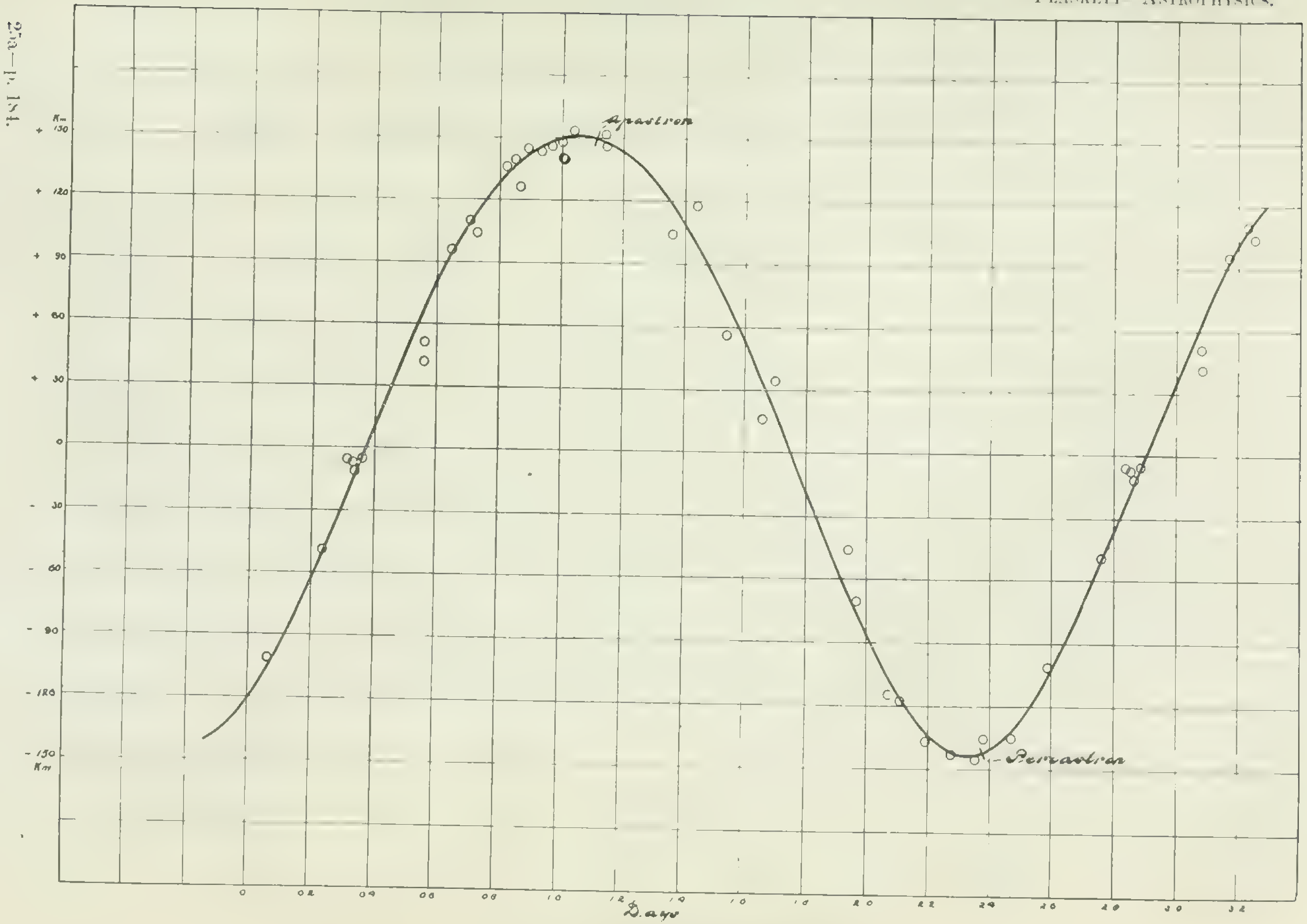


FIG. 8—Velocity Curve of ψ Orionis.

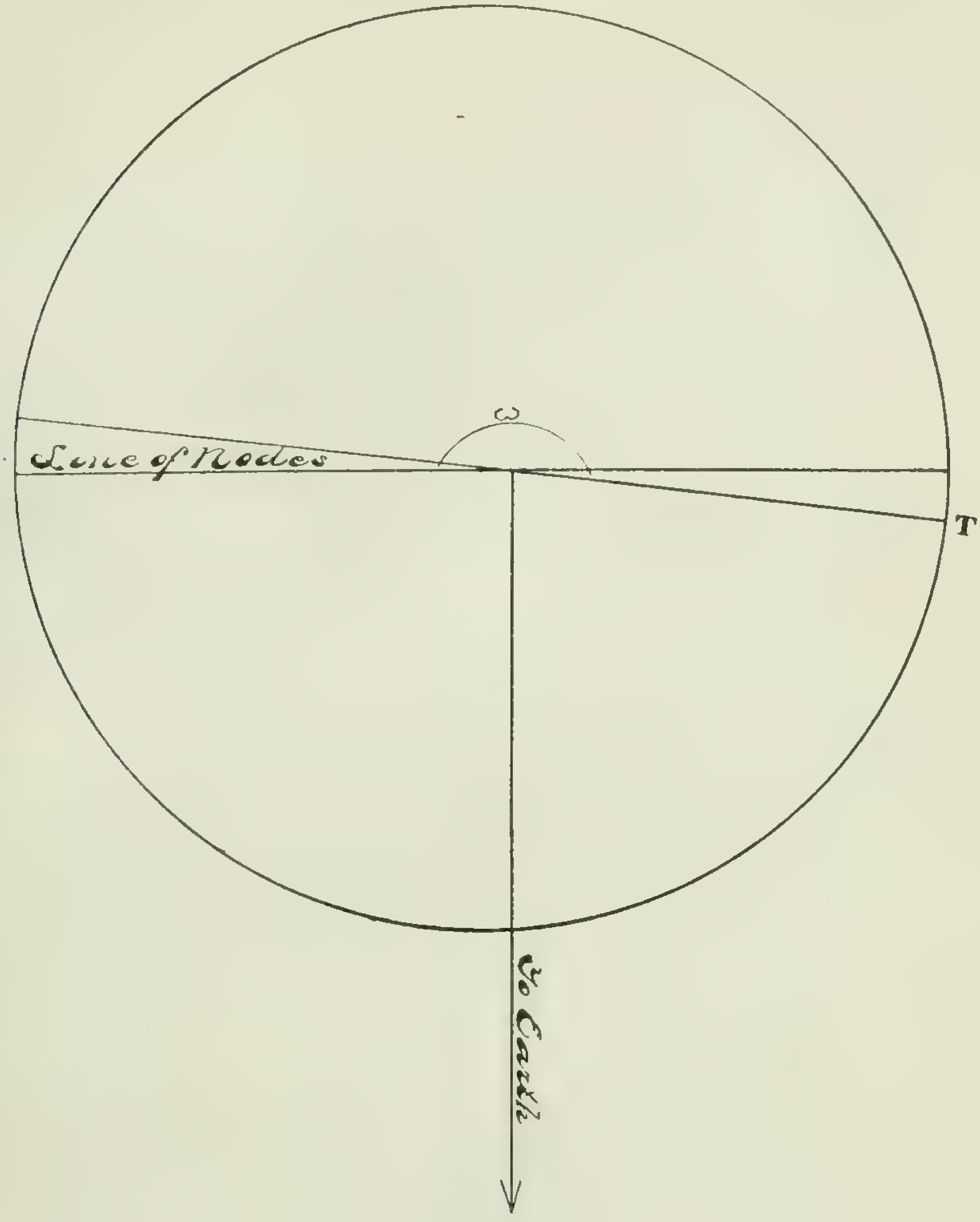


Fig. 9—Orbit of ψ Orionis.

Addendum.

A least squares solution has been applied to this orbit as to ι Orionis and has resulted in considerable improvement in the elements.

As was pointed out above the highest residuals occur in the ascending and descending branches of the curve and it was considered advisable to treat the Ottawa observations only and see if these residuals could be reduced by a change in the period. Taking as provisional elements those determined above, and reducing the 37 observations to 29 suitably weighted places by combining plates taken successively on the same nights, we obtain the observation equations below. The coefficients of the five unknowns were computed from the formulæ of Lehmann-Filhes, and a sixth unknown of coefficient unity was added as a correction to the velocity of the system.

To make the observation equations homogeneous the following substitutions were made:—

$$x = \delta K$$
$$y = K\delta e \qquad = \quad 147{\cdot}2\delta e$$
$$z = K\delta\omega \qquad = \quad 147{\cdot}2\delta\omega$$
$$u = \frac{100\ K}{(1-e^2)^{3/2}}\ \delta\mu = 14801{\cdot}7\delta\mu$$
$$v = \frac{K\mu}{(1-e^2)^{3/2}}\ \delta T = \quad 368{\cdot}18\delta T$$
$$w = \delta\gamma$$

1ST OBSERVATION EQUATIONS ψ ORIONIS.

x.	y.	z.	u.	v.	w.	s.	Wt.
−1·050	976	+ ·167	·142	·181	+1·000	− 6·99	1
− ·978	·740	+ ·410	+ ·454	453	"	+ 3·51	1
·802	·173	+ ·680	+ ·358	· ·743	"	− 9 55	1
− ·401	+ ·730	+ ·948	+ ·757	993	"	+ 2·41	1
− ·173	+ ·968	+1·001	+ ·392	1·021	"	− 4·46	2
− ·135	+ 988	+1·004	+ ·288	−1 020	"	− 1·38	2
+ ·381	+ 674	+ ·903	− ·210	·857	"	+26·81	1
+ ·381	+ ·674	+ ·903	+ ·353	· 857	"	+17·51	1
+ ·560	+ ·307	+ 789	+ ·688	·730	"	− 0·69	1
+ ·647	+ 081	+ 711	+ ·580	650	"	− 2·57	1
+ ·694	·057	+ ·661	+ ·444	·598	"	+10·63	1
+ ·726	504	+ ·464	− ·006	− ·411	"	− 4·81	2
+ ·851	·597	+ ·413	+ ·233	· ·364	"	+11·67	1
+ ·908	·837	+ ·245	+ ·125	·211	"	+ 2·55	1
+ ·927	·927	+ 148	+ ·033	·124	"	+ 1·93	2
+ ·931	950	+ ·115	+ ·614	·095	"	+ 9·04	1
+ ·933	962	+ ·093	+ ·037	· ·076	"	+10·75	1
+ ·936	· 982	+ ·049	+ ·020	·037	"	+ 0·27	3
+ ·913	·945	− ·213	− ·756	+ ·193	"	+ 3·81	1
+ ·711	313	·627	− ·440	+ ·569	"	+13·73	1
+ ·584	+ ·033	− ·756	− ·362	+ 695	"	−17·83	1
+ ·392	+ ·478	− 884	434	+ ·830	"	+13·59	1
+ ·124	+ ·877	·976	− ·448	+ ·947	"	+14·18	1
+ ·028	+ ·955	·989	− ·779	+ ·972	"	−20·53	1
− ·591	+ ·559	− 842	− ·200	+ ·896	"	−15·42	2
− ·859	·016	·599	− ·299	+ ·662	"	+ 1·93	2
− ·993	·644	− 360	− ·320	+ 409	"	+ 2·98	1
1 055	· 938	·114	− ·100	+ ·136	"	− 2·52	1
−1·060	·999	084	− ·011	+ ·087	"	+ 1·94	1

There result the following normal equations.

$$\begin{array}{r}
+20{\cdot}398x - 5{\cdot}255y + 2{\cdot}618z + {\cdot}471u - 2{\cdot}431v + 5{\cdot}297w + 85{\cdot}859 \\
+20{\cdot}726y + 1{\cdot}446z + {\cdot}288u - 1{\cdot}687v - 5{\cdot}132w - 31{\cdot}490 \\
+15{\cdot}514z + 7{\cdot}241u - 15{\cdot}392v + 4{\cdot}702w + 55{\cdot}912 \\
+5{\cdot}291u - 7{\cdot}169v + 1{\cdot}401w + 13{\cdot}180 \\
+15{\cdot}337v - 4{\cdot}291w - 54{\cdot}156 \\
+37{\cdot}000w + 38{\cdot}800
\end{array}$$

It will be noticed that the normals in z and v ($\delta\omega$ and δT) are practically identical, and it will be impossible to accurately determine their values separately, owing to the smallness of the coefficients in the elimination. Consequently, $\delta\omega$ and δT were successively assumed to be zero, and we obtain the following corrected elements from these two solutions:—

	Preliminary.	For $\delta T = 0$	For $\delta\omega = 0$
K	147·2	143·843	143·799
e	0·063	0·06992	0·07012
ω	186°	183°·736	186°
Period U	2·526 dys.	2·52561 dys.	2·52563 dys.
T	2·36 "	2·36 "	2·3753 "
γ	+ 12·42 km.	12·517 km.	12·453 km.

As there is relatively less change in T than in ω in the two cases, the first set only will be considered. The change in the period is small, showing that no improvement can be effected in the Ottawa observations by any marked change in this variable, and it can now be finally determined by means of the three early observations of Frost and Adams with the aid of three additional plates kindly sent me by Prof. Frost. Two of the latter, the third being unsuitable, were carefully measured by Mr. Harper, and the use of the five measures, three of 1903, one each of 1904 and 1905, gave as the only permissible period 2·52588 days, which can not be in error more than one unit in the last place. The positions of these observations on the curve are shown by the crosses in Fig. 10. The residuals are no larger than is to be expected from spectra so uncertain and difficult of measurement as these.

In the final solution then a correction for the period was omitted. As provisional elements were taken (in round numbers) those obtained by the first solution.

Period = 2·52588 dys.	ω = 185°
K = 144·0	T = 2·36 dys.
e = 0·07	γ = 12·5 km.

The observations with their corrected phases were grouped into 19 normal places, (table of normal places and residuals), from which were obtained 19 observation equations by using the same substitutions for homogeneity as before.

2ND OBSERVATION EQUATIONS ψ ORIONIS.

x.	y.	z.	v.	w.	l.	Wt.
−1·065	·993	·107	116	+1·000	− ·50	2
− ·985	− 729	+ ·409	·459	"	+ 5·69	1
− ·802	·140	+ ·687	758	"	− 1·76	1
- ·400	+ ·741	+ ·950	·999	"	+ 3·94	1
− ·176	+ 959	+1 000	1·021	"	− 5·54	4
+ ·376	+ ·641	+ ·901	·850	"	+20·18	2
+ ·565	+ 165	+ 779	·713	"	− 1·74	1
+ ·670	·037	+ ·679	·610	"	+ 2·03	2
+ ·832	·571	+ ·439	·382	"	− 1·31	3
+ ·895	·822	+ ·268	228	"	− 3·26	3
+ ·927	- ·972	+ ·083	·067	"	+ 0·43	4
+ ·913	− 962	177	+ ·158	"	− 3·27	2
+ ·654	162	684	+ 616	"	− 3·00	2
+ ·401	+ 447	·876	+ 816	"	+13·60	1
+ ·104	+ 879	·979	+ ·949	"	+ 2·11	2
− ·560	+ ·607	- 865	·923	"	9·94	2
− ·853	- ·124	615	+ ·686	"	+ 5·44	2
−1·003	·654	·553	- ·405	"	+ 4·78	1
−1·061	- 936	127	·152	"	+ 0·21	1

From these observation equations result the normal equations.

$$+20{\cdot}556x - 5{\cdot}145y + 2{\cdot}629z - 2{\cdot}397v + 5{\cdot}351w - 1{\cdot}617 = 0$$
$$+20{\cdot}106y + 1{\cdot}334z - 1{\cdot}600v - 5{\cdot}639w + 13{\cdot}118 = 0$$
$$+15{\cdot}614z - 15{\cdot}465v + 4{\cdot}656w + 14{\cdot}165 = 0$$
$$15{\cdot}398v - 4{\cdot}282w - 13{\cdot}127 = 0$$
$$+37{\cdot}000w + 16{\cdot}670 = 0$$

Again the normals in z and v are nearly identical. Assuming v or $\delta T = 0$ the solution gives

$$
\begin{array}{lll}
x = +\cdot1198 & \delta K = +\cdot1198 & \pm\ 1\cdot582 \text{ km.} \\
y = -\cdot7099 & \delta e = -\cdot00493 & \pm\ \cdot01116 \\
z = -\cdot7225 & \delta\omega = -\cdot005015 = -\ \cdot286^\circ & \pm\ 710^\circ \\
w = -\cdot4851 & \delta\gamma = -\cdot4851 & \pm\ 1\cdot177 \text{ km.}
\end{array}
$$

giving for the final elements.

$$
\begin{array}{rl}
K = & 144\cdot12 \ \pm\ 1\cdot58 \text{ km.} \\
e = & 0\cdot0651 \ \pm\ \cdot0112 \\
\omega = & 184^\circ\cdot71 \ \pm\ \cdot71^\circ \\
U = & 2\cdot52588 \text{ dys.} \\
T = & 2{,}417{,}916\cdot36 \text{ Julian date.} \\
\gamma = & 12\cdot015 \text{ km.} \ \pm\ 1\cdot177 \text{ km.} \\
a \sin i = & 4{,}995{,}100 \text{ km.}
\end{array}
$$

NORMAL PLACES AND RESIDUALS.

No. of Plates.	Total Difference of Phase.	Mean Phase from T.	Mean Velocity.	Wt.	C — O Prel.	C — O Final.	Eph. — Equation.
2	.036	·005	140·3	2	— 2·7	— ·5	·00
1	....	·115	—135·0	1	+ 6·6	+ 5·4	− ·18
1	....	·233	—101·2	1	— 2·5	— 2·7	+ ·02
1	....	·411	— 49·0	1	+ 4·1	+ 2·0	— ·17
4	·044	·499	— 7·3	4	— 4·6	— 7·5	— ·02
2	·013	·7285	+ 46·4	2	+22·9	+18·6	— ·05
1	....	·825	+ 95·6	1	+ 1·5	— 2·9	— ·08
2	·023	·8885	+107·0	2	+ 5·9	+ 1·1	— ·03
3	·039	1·018	+133·6	3	— ·1	— 1·6	— ·02
3	·089	1·101	+144·7	3	+ 1·0	— 3·3	— ·01
4	·053	1·187	+145·6	4	+ 4·5	+ ·7	— ·01
2	·001	1·3075	+147·3	2	— ·1	— 2·8	·00
2	·079	1·5705	+109·7	2	— 2·6	— 2·7	+ ·05
1	....	1·711	+ 56·6	1	+12·0	+13·4	— ·04
2	·050	1·844	+ 25·4	2	— 1·1	+ 1·7	+ ·01
2	·031	2·1155	— 58·2	2	—14·6	—10·3	— ·02
2	·039	2·2585	—115·8	2	+ 1·2	+ 5·4	— ·01
1	....	2·363	—136·7	1	+ 1·8	+ 5·2	− ·25
1	....	2·449	—140·4	1	— 2·7	+ ·3	— ·08

A comparison of the residuals obtained on the one hand by computing an ephemeris from these elements, and on the other by substituting the values of the unknowns in the observation equations shows that the solution is satisfactory. The resulting velocity curve with the normal places plotted as circles is given in Fig. 10. Σpvv is reduced from 1970·3 to 1522·5, the probable error of an observation of weight unity from ± 7·7 km. to ± 6·8 km. The only change from the original elements of appreciable magnitude is in K, which is reduced by about 3 km. Three rather high residuals all occurring on the inclined parts of the curve may account for part of this change. As previously mentioned, part of the discrepancy in these three places, beyond that due to the character of the spectrum, may be explained, in a very short period binary, by inaccuracy in phase determination due to unsymmetrical exposure. The very large range of velocity 288 km., the highest in this type of binary known to the writer, is undoubtedly a considerable factor in obtaining satisfactory elements, which in this case may be considered as fairly closely determined. Apparently as in ι Orionis the least squares solution has improved the geometrically determined elements.

This concludes my portion of the report.

25a—p. 188.

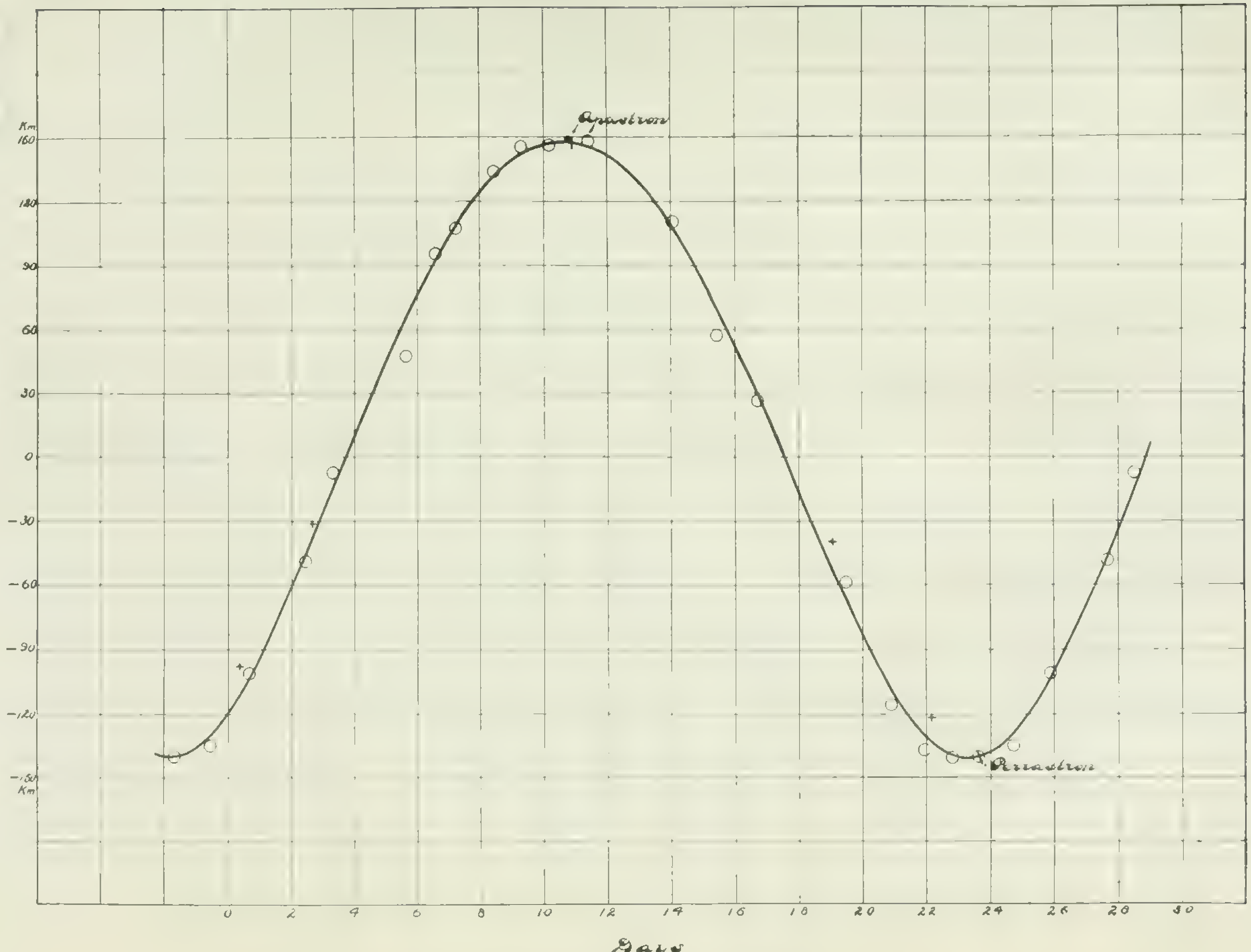


FIG. 10—Velocity Curve ψ Orionis.

In addition, as appendices, follow the reports of Mr. Harper on the spectroscopic binaries η Virginis and θ Aquilae; of Mr. Motherwell on measurements of double stars and on observed occultations of the moon; of Dr. DeLury on the wave lengths of lines in the Iron-Vanadium alloy used for the comparison spark in the spectrograph; and of Mr. Tobey on photometric work.

In conclusion, I wish to again express my appreciation of the help and encouragement you were always so willing to give in any difficulties that arose.

I have the honour to be, sir,

Your obedient servant,

J. S. PLASKETT.

APPENDIX A.

η VIRGINIS.

W. E. HARPER.

The star η Virginis $\alpha = 12^h\ 14{\cdot}8^m$, $\delta = -0°\ 6'$, photographic magnitude 4·2, was announced as a spectroscopic binary in Astrophysical Journal XVII, 150, 1903, by Frost and Adams, also in L.O.B. No. 46, 1903, by Campbell and Curtiss. It has a composite spectrum, both components belonging to Vogel's type I*a*2, or Miss Maury's VIII*a*. The lines of the fainter component were, owing to their weakness, only occasionally measured in our plates and the results obtained were, therefore, derived from a consideration of the spectrum of the brighter component only.

Forty-three measurable negatives of this star were obtained between February 22 and July 5, 1907. The first thirty-two negatives were made with the Universal spectroscope as adapted for radial-velocity work, the dispersion at $H\gamma$ (λ 4340) being 18·6 tenth-metres per mm. Some five or six were made with the new three-prism spectrograph, whose linear dispersion at λ 4415 is 11·1 tenth-meters per mm. The balance were made with the new single-prism spectrograph whose linear dispersion at λ 4415 is about 32·4 tenth-meters per mm. In fair seeing the exposure time required was for the single-prism spectrograph from 35 to 40 minutes; for the Universal three-prism spectrograph from 60 to 65 minutes, while for the new three-prism spectrograph a considerably longer exposure was necessary.

The three-prism plates were all reduced by the aid of the Hartmann interpolation formula

$$\lambda = \lambda_0 + \frac{c}{s_0 - s}$$

which method was discussed in detail in the report for the year 1905-6. I may say, however, that the constants λ_0, c and s_0 were not always determined for each plate. When there were several plates made at or about the same temperature a uniform set of constants was adopted in their reduction. This can introduce no appreciable error in the final result as the formula is purely arbitrary and affects both star and comparison lines alike. The differences between the computed value of the comparison lines by the formula and their true values when plotted as ordinates, with the corresponding wave-lengths as abscissae, give us a curve from which corrections can be made to the computed values of the star lines.

Five of the later plates made with the single prism were reduced by the short method recently adopted here and described in the report for last year. The micrometer settings corresponding to the wave-lengths of the comparison and star lines are determined, and when the settings for the star lines have been corrected by means of the comparison settings, the displacement is got directly in revolutions of the micrometer head. The following tables give the settings used in these plates for the comparison and star lines, and in the case of the latter the velocity corresponding to a revolution of the micrometer head is attached.

FE. V. COMPARISON LINES.

Wave-Length.	Micrometer Setting.		Wave-Length.	Micrometer Setting.	
	20°	30°		20°	30°
4864·943	72·9636	73·0098	4482·413	54·0153	54·0288
4851·686	72·3993	72·4449	4452·180	52·2398	52·2490
4594·216	60·1873	60·2143	4404·929	49·3658	49·3676
4586·554	59·7830	59·8092	4395·382	48·7700	48·7700
4549·642	57·7979	57·8200	4325·941	44·2724	44·2593
4528·798	56·6488	56·6684	4260·656	39·7637	39·7361
4494·755	54·7266	54·7419	4202·195	35·4730	35·4302

STELLAR LINES.

Wave-Length.	20°		30°	
	Velocities per Revn.	Micrometer Reading.	Velocities per Revn.	Micrometer Reading.
4861·527	1452·8	72·8187	1451·2	72·8646
4584·018	1233·0	59·6486	1230·5	59·6745
4549·766	1206·4	57·8047	1203·8	57·8268
4534·139	1194·3	56·9453	1191·6	56·9655
4501·448	1169·1	55·1091	1166·4	55·1252
4481·400	1153·7	53·9566	1150·9	53·9698
4468·663	1144·0	53·2138	1141·2	53·2253
4437·718	1120·3	51·1732	1117·4	51·3802
4404·927	1095·4	49·3657	1092·4	49·3674
4395·286	1088·1	48·7640	1085·1	48·7640
4325·939	1035·9	44·2723	1032·7	44·2592
4271·760	995·5	40·5509	992·2	40·5259
4215·668	954·2	36·4836	950·8	36·4450

Of course the above star lines are only those which happen to be used in the plates reduced by the short method. The table which follows contains all the more important star lines which have been employed. For the sake of brevity those which have been used but rarely are not included, but the wave-lengths employed in such cases are given in column three of the detailed statement of the measures and reductions. The first column of the table signifies the element or elements to which the particular line is due, and for the sake of completeness the value of a displacement of one tenth-meter in kilometers per second for the various wave-lengths given is also included. The lines, other than the magnesium at λ 4481 and $H\gamma$ (λ 4340), are mostly all enhanced lines of iron and titanium. In this connection the 'Tables of Wave-Lengths of Enhanced Lines' issued in 1906 from the Solar Physics Observatory, South Kensington by Sir Norman Lockyer have been of material assistance.

LINES USED IN η VIRGINIS.

Elements.	Wave-Length.	No. of km. per tenth-meter.	Elements.	Wave-Length.	No. of km. per tenth-meter.
Fe	4584·018	65·41	Fe	4404·927	68·07
Ti	4572·156	65·58	Ti. V. Zr.	4395·286	68·20
Ti	4563·939	65·71	Fe	4383·720	68·41
Cr.	4558·827	65·78	Fe. Ti. Fe.	4367·840	68·66
Fe; Ti-Co.	4549·766	65·91	Cr. Mg.	4352·006	68·88
Ti-Co.	4534·139	66·13	H.	4340·634	69·07
Ti; Fe.	4522·855	66·30	Fe	4325·939	69·32
Fe?	4520·397	66·33	Fe. Ti	4315·178	69·48
–	4515·508	66·39	Ti	4313·034	69·49
Fe?	4508·455	66·52	Fe	4308·081	69·60
Ti	4501·448	66·60	Ti	4300·211	69·73
Mg	4481·400	66·91	Ti. Fe	4294·273	69·82
Ti	4468·663	67·10	Fe	4260·640	70·39
Ti	4443·976	67·48	–	4246·996	70·60
–	4416·985	67·89	Fe	4233·328	70·83
Fe	4415·293	67·90	Fe	4216·351	71·10
Ti	4411·205	67·96	Fe. Sr	4215·668	71·11

JOURNAL OF OBSERVATIONS.

The extract given below from the regular observing journal furnishes the observational data for all the plates discussed here. Most of the columns are self explanatory and need not be enlarged upon. The three cameras used were III B, three-prism, Universal spectroscope of Brashear; III L, three-prism long focus and I L, one-prism long focus. The middle of exposure is given in eastern standard or 75th meridian time. Some confusion might arise in the case of stars observed after midnight. For instance, No. 638 is recorded as February 25th 1^h 50^m, whereas to be strictly accurate it should be February 26th 1^h 50^m. In future I think it would be well on making the entry in the record of spectrograms to use Greenwich Mean Time as is used in the summary of velocities. Formerly the comparison was exposed at the beginning and end of the star exposure; lately this has been changed to four exposures of the comparison arranged so that they occur at the middle of each quarter of the exposure on the star. The slit-width is given in inches.

RECORD OF SPECTROGRAMS.

Star.	No. of Negative.	Camera.	Plate.	Date.	Middle of Exposure. E. S. T.	Duration.	Hour Angle at end.	Comparison Spectrum. Beginning.	Comparison Spectrum. End.	Comparison Spectrum. Kind.	Temperature. Room. Beginning.	Temperature. Room. End.	Temperature. Prism Box. Beginning.	Temperature. Prism Box. End.	Slit Width.	Focal Position. Star Focus.	Focal Position. Collimator.	Focal Position. Camera.	Seeing.	Observer.	Remarks.
				1907.	h. m.	m	h. m.	s.	s.		Fahr.	Fahr.	Cent.	Cent.	m. m.						
α Virginis.	629	III B..	Seed 27.	Feb. 22	12 57	55	0 43 E	20	20	Fe. Spark.	0·8	3·8	−15·0	−15·0	·0013	20 3	15·2	5·65	Good....	P	
" .	638	" ..	" 27.	" 25	1 50	55	0 20 W	20	20	"	7·5	6·3	− 9·8	− 9 8	·0013	20·5	15·2	5·67	Fair to good	P	
" .	651	" ..	" 27.	Mar. 6	11 15	60	1 40 E	20	20	"	22·0	20·5	+ 3·8	+ 3 8	·0013	20 5	15·2	5·70	Fair	P	
" .	652	" .	" 27.	" 6	1 58	60	1 05 W	20	20	"	18 0	17·0	+ 1·5	+ 1·2	·0013	20·5	15·2	5·70	"	P	
" .	656	" ..	" 27.	" 8	11 15	70	1 25 E	20	20	"	28·5	28·0	+ 3·2	+ 3·1	·0013	20·5	15·2	5·70	"	P	
" .	658	"	" 27.	" 8	2 33	54	1 45 W	20	20	"	25·6	24·0	1·5	1·6	·0013	20 5	15·2	5·70	" ...	P	
" .	663	"	" 27.	" 11	11 22	55	1 10 E	20	20	"	32·0	32·2	6 8	6·8	·0013	20 5	15 2	5·72	"	P	
" .	664	" ..	" 27.	" 11	2 05	50	1 25 W	20	20	"	28·3	26·5	7 1	7 0	·0013	20·5	15 2	5·72	"	P	
" .	668	" ..	" 27	" 20	10 43	73	1 05 E	20	20	"	31·2	30·0	3·8	3 8	·0013	20·5	15·2	5 70	Good....	P	
"	671	" ..	" 27	" 20	2 36	60	2 40 W	20	20	"	28·3	28·0	2·9	2 9	·0013	20 5	15·2	5·70	"	P	
" .	675	" ..	" 27.	" 28	9 05	91	2 07 E	20	20	"	52·0	49 7	15·0	15·0	·0012	20 5	15·2	5·80	"	H	Clouds 15ᵐ
" .	689	" ..	" 27.	Apr. 3	10 10	70	0 45 E	25	25	"	41·5	39·8	11·0	11·0	·0010	20·5	15 2	5·72	Hazy	P	
" .	690	" ..	" 27.	" 3	11 17	55	0 15 W	25	25	"	39·8	38·3	11 0	10·5	·0013	20·5	15·2	5·72	"	P	
" .	697	" ..	" 27.	" 5	10 58	50	0 00	25	25	"	30·6	31·0	5 7	5·7	·0013	18·2	15·2	5·73	Good......	P	
"	700	" ..	" 27.	" 5	2 25	40	3 20 W	25	25	"	27 2	25·7	4·9	4 9	·0013	18·2	15·2	5·73	"	P	
"	706	" .	" 27.	" 11	12 13	50	1 35 W	25	25	"	38·0	37·5	8 3	8·3	·0013	18·2	15 2	5·73	"	H	
"	707	" ..	" 27.	" 11	1 07	55	2 30 W	25	25	"	37 5	35·5	8·3	8 3	·0013	18·2	15·2	5·73	Getting hazy	H	
" .	710	"	" 27.	" 15	8 52	57	1 25 E	25	25	"	40·0	38·6	9·9	10 0	·0013	18·2	15·2	5·76	Fair......	P	
" .	715	" ..	" 27.	" 18	8 07	55	2 00 E	25	25	"	41·6	40·0	9·0	9·1	·0013	18·5	15·2	5·78	Good.......	H	
" .	722	" .	" 27	" 18	11 25	60	2 20 W	25	25	"	36·4	36 4	9 0	9·0	·0011	18·5	15·2	5·78	"	H	
"	723	" ..	" 27.	" 18	12 57	66	3 56 W	25	25	"	36·0	35·0	9·0	9·0	·0011	18·5	15·2	5 78	"	H	
" .	725	" ..	" 27.	" 19	8 19	55	1 45 E	25	25	"	44 8	43·6	11·0	11·0	·0013	18 5	15·2	5·79	"	P	
" .	728	" ..	" 27.	" 19	10 12	56	0 10 W	25	25	"	40·6	36 3	10·9	10·2	·0013	18 5	15·2	5·79	"	P	
" .	729	" ..	" 27.	" 19	11 02	35	0 50 W	25	25	"	36 0	35·0	10·2	10·2	·0013	18·5	15·2	5·79	"	P	Stopped by clouds.
" .	730	" ..	" 27.	" 19	12 50	51	2 40 W	25	25	"	36·0	34·4	10·6	10 2	·0013	18·5	15 2	5·79	Poor	P	Cloudy.
" .	735	" ..	" 27.	" 24	9 03	60	0 40 E	6-6	6 6	"	48·6	47·5	14·1	14·2	·0013	18·5	15·2	5·81	Clouds.	P	
" .	737	" ..	" 27.	" 24	10 25	50	0 40 W	6-6	6 6	"	48 0	46·0	14·3	14·2	·0013	18 5	15 2	5 81	Hazy	P	Underexposed.
" .	738	" ..	" 27.	" 26	11 20	50	1 45 W	6 6	6-6	"	44·0	42·5	8·6	8·7	·0013	18·5	15·2	5 79	Fair	P	
" .	740	" ..	" 27.	" 27	11 10	40	1 30 W	6-6-	6 6	"	48·8	48 3	11·7	11·8	·0013	18·5	15·2	5·80	"	P	
" .	742	" ..	" 27.	May 2	8 22	45	1 08 E	6-10	6	"	55 4	54·0	16·7	16·7	·0013	18 5	15·2	5·79	Hazy	H	
" .	748	" ..	" 27.	" 4	11 27	45	2 15 W	6 6-	6-6	"	34·8	32·3	3·9	4 2	·0013	18 5	15·2	5·79	Fair	P	
" .	751	" ..	" 27.	" 7	8 32	65	0 15 E	6 6	12	"	55·5	50 5	16·1	16·1	·0013	18·0	15·2	5·79	"	H	
" .	754	" ..	" 27.	" 9	8 30	65	0 13 E	6 6	6 6	"	60·0	58 0	19·8	19·8	·0013	18·0	15·2	5·82	Unsteady ..	H	

													Centigrade									
"	757	IIIL..	"	27.	"	14	10	12	90	2 06 W	4-4-4-4	Fe. V spark	12·5	12·0	15·1	15·1	·0015	44·6	10·8	18·3	Clouds.. ...	H
"	761	"	"	27	"	18	11	05	50	0 30 W	4 4-4-4	"	15·5	15·5	17·2	17·2	·0015	44·6	10·8	18·36	Very poor ..	P
"	763	"	"	27	"	20	10	07	96	2 24 W	4-4 4-4	"	7·0	6·0	9·2	9·2	·0015	44·6	10·8	18·2	Unsteady...	H
"	773	IL ..	"	27.	"	23	8	36	36	0 37 W	4-4 4-4	"	16·0	15·5	17·3	17·3	·0012	45·0	10·8	18·3	Fair	H
"	777	"	"	27.	"	24	8	25	30	0 30 W	5 7 4	"	14·5	13·6	16·4	16·4	·0010	45·0	10·8	18·4	Good.......	P
"	789	"	"	27.	"	29	9	45	30	2 05 W	2-2-2-2	"	9·0	8·9	14·5	14·5	·0010	45·0	10·8	18·46	Fair	P
"	795	"	"	27	"	31	9	06	27	1 35 W	2-2-2-2	"	15·5	15·5	19·0	19·0	·0010	45·5	10·8	18·58	Good......	P
"	811	"	"	27.	June	10	8	35	35	1 48 W	2-2-2-2	"	16·6	15·6	18·2	18·0	·0009	45·6	10·8	18·61	"	P
"	822	"	"	27.	"	11	8	28	31	1 42 W	3 3 3 3	"	18·2	17·6	19·4	19·4	·0010	45·6	10·8	18·68	"	H
"	835	IIIL..	"	27.	"	12	9	35	55	3 05 W	6-6-6-6	"	22·1	21·0	23·15	23·1	·0020	44·5	10·8	18·72	"	P
"	915	IL ..	"	27.	July	5	9	02	35	3 50 W	2 5-3	"	22·6	22·6	26·45	26·4	·0011	45·0	10·8	18·64	Poor	P

Detailed Measures and Reductions.

The following section contains the results of measures upon the plates of this star. Each plate was measured in two positions on the microscope, red end to right and red end to left, four settings being made on each line in each position. The mean of the settings is found in column 1. The second column contains the computed values for the comparison lines and the values for the star lines corrected by means of the comparison lines as previously described. The normal wave-length and the displacement in tenth-meters with the corresponding velocity follows.

The symbols V_a and V_d are employed in the reduction of the stars velocity to the sun, V_a denoting the correction due to the velocity of the earth in its orbit, and V_d the correction due to the earth's diurnal rotation. The corrections for the orbital velocity have been made with the use of Schlesinger's tables* of star constants, and the diurnal corrections are taken from a table constructed for the latitude of this observatory.

η VIRGINIS 629.

1907. Feb. 22.
G. M. T. $17^h\ 57^m$

Observed by } J. S. Plaskett.
Measured by }

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·8605	4584 215	....	....	... .	56·7667	4404·927	....	....	....
72·8181	4583·510	·018	·508	—33·12	54·6233	4383·729	....	....	....
71·8508	4571·639	·156	·517	33·91	54·5796	4383·312	·720	·408	27·91
70·7572	4558·403	·827	·424	27·90	52·9317	4367·407	·841	·434	29·82
70·0215	4549·738	....	....	....	51·2621	4351·611	·006	·396	27·28
69·9936	4549·276	·766	·490	32·29	50·0402	4340 254	·634	·380	26·26
68·2527	4528·922	....	....	....	48·4730	4325 895	... .	... .	... .
67·7000	4522·399	·855	·456	30·23	46·4779	4308·031	....	....	....
66·4465	4507 986	·455	·469	31·24	46·4204	4307·573	·081	·508	35 36
65·8133	4500·926	·448	·522	34·77	44·9061	4294·248	... ...	....	....
65·2605	4494·813	....	....	.. ..	44 8673	4293·964	·286	·322	22·51
64·0121	4480·902	·400	·498	33·31	44 1533	4287·793	·162	·369	25·79
63·5828	4476·269	....	....	....	35·3121	4215·386	·668	·282	—20·05
62·8473	4468·204	·663	·459	30·80	33·6020	4202·078	....	....	....
57·7567	4414·902	·293	·391	26·55					

Mean..— 29·40
V_a..................................+ 26·05
V_d..................................+ ·06
Curvature..................................— ·50

Radial velocity. ....— 3·

$\epsilon = \pm 3{\cdot}2$
$\epsilon_0 = \pm 0{\cdot}8$

* Astrophysical Journal, Vol. X, p. 1-13.

η VIRGINIS 638.

1907. Feb. 25.
G. M. T. $18^h\ 50^m$

Observed by } W. E. Harper.
Measured by }

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·8924	4584·537	....	....	....	54·6305	4383·727	....	....	....
72·8843	4583·918	·018	·100	− 6·52	54·6173	4383·591	·720	·129	8·81
71·2327	4573·695	·899	204	13·34	51·2892	4351 853	006	·153	10·54
70·0535	4550·046	....	....	....	50·0651	4340·485	·634	·149	10·30
70 0386	4549·465	·766	·301	19·84	48·4718	4325·812	....	....	....
68 7083	4533·839	·139	·300	19·84	46·4732	4307·917	....	....	....
68 7307	4534·100	·340	·240	15·86	46·4452	4307·744	·081	·337	23·45
68·2783	4529 145	....	....	....	45·5514	4299·995	211	·217	15·12
67·1044	4515·309	·508	·199	13·21	45·4561	4299·163	·410	·247	17·24
66·4858	4508·264	·455	191	12·72	44·8974	4294·100	....	....	....
65·8585	4501·185	·448	·263	17·52	44·8763	4294·116	·301	·185	12·91
65·2810	4494·970	....	....	....	40 9302	4260·408	....	....	....
64·0512	4481·094	·400	·306	20·47	40·9030	4260·423	·640	·217	15·28
63·6044	4476·434	....	....	....	37·5430	4233·149	·328	·179	12·67
57 9498	4416·699	·985	·286	19·42	35·2971	4215 466	·668	·202	−14·36
57·7780	4414·954	·293	·339	23·02	33·5730	4201 784	....	....	....
56·7780	4404·968	....	....	....					

Mean................		− 15·36
V_a	+ 13 37	
V_d	+ ·02	
Curvature		− ·50
Radial velocity.......		− 2·5

η VIRGINIS 651.

1907. March 6.
G. M. T. $16^h\ 15^m$

Observed by } J. S. Plaskett.
Measured by }

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9885	4584·653	·018	·635	[+41·53]	54 5475	4383·075	·720	·645	44·12
72·9390	4584·388	....	....	....	54·6144	4383·756	....	....	....
72·8845	4583·346	·018	·672	−43·81	51·1925	4351·180	·006	·826	56·91
70·0296	4548·930	·766	·836	54·84	49·9602	4339·784	·634	·850	58·50
70·0897	4549·923	....	....	....	48·4362	4325·898	....	....	....
68·6938	4533·264	·139	·875	57·84	46·9251	4312·444	·034	·590	41·06
68·3052	4529·007	....	....	....	46·4298	4308·006	....	....	....
67·0851	4514·797	·508	·711	47·21	46·3632	4307·493	·081	·588	40·93
66·4547	4507·759	·455	·696	46·34	45·8138	4302·671	·503	·832	57·99
65·3024	4494·916	....	....	....	44·7667	4293·580	·386	·706	48·93
64·0243	4480·640	·400	·760	50·84	40·9444	4261·286	·640	·646	[+45·48]
63·6163	4476·356	....	....	....	37·4296	4232·844	·594	·750	53·10
57·9062	4416·308	·985	·677	45·90	35·1568	4215·023	·668	·645	45·86
56·7684	4404·971	....	....	....	33·4831	4201·919	....	....	....
56·7125	4404·369	·927	·558	37·83	30·3001	4178·382	·025	·643	−46·17
54·7180	4384·727	·548	·821	56·16					

Mean.		−49·18
V_a	+9·73	
V_d	+ ·17	
Curvature...........		− ·50
Radial velocity		−39·8

η VIRGINIS 652.

1907. Mar. 6.
G. M. T. $18^h\ 58^m$

Observed by } Measured by } J. S. PLASKETT.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9232	4584·193	....	....	....	56·7622	4404·909	....	....	....
72·8801	4583·487	·018	·531	− 34·62	56·8363	4405·667	·927	740	[+ 50·39]
70·7944	4558·194	·827	·633	41·52	56·7137	4404·443	·927	·516	35·14
70·5609	4555·403	·030	·627	41·13	54·7210	4384·812	·548	·736	50·34
70·0202	4548·986	766	·780	51·35	54·5420	4383·072	·720	·648	44·32
70·0756	4549·756	....	....	....	54·6087	4383·700	....	....	....
68·6917	4533·435	·139	704	46·53	51·2192	4351·465	·006	·541	37·27
68·2906	4528·838	....	....	....	48·4362	4325·898	....	....	....
65·2891	4494·768	....	....	....	47·8298	4320·491	·992	·501	34·77
64·0204	4480·727	·400	·673	45·02	46·5194	4308·845	·081	·764	[+ 53·17]
63·6046	4476·229	....	....	....	46·3617	4307·456	·081	·625	43·50
62·8374	4467·888	·663	·780	52·34	46·4329	4308·029	....	....	....
60·5203	4443·303	·976	·673	45·49	40·8739	4260·579	....	....	....
58·0040	4417·402	·038	·636	43·18	40·7960	4259·995	·640	·645	45·41
57·8968	4416·318	·985	·667	45·29	35·1987	4215·192	·668	·476	− 33·84

Mean		− 42·84
V_a	+ 9·67	
V_d		− ·04
Curvature....................		− ·50
Radial velocity		− 33·7

η VIRGINIS 656.

1907. Mar. 8.
G. M. T. $16^h\ 15^m$

Observed by } Measured by } J. S. PLASKETT.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9533	4584·364	....	....	....	56·7196	4404·324	·927	·603	41·06
72·8747	4583·049	·018	·969	— 63·18	55·8780	4395·982	·296	·696	[+ 47·47]
71·9147	4571·366	·156	·790	51·67	55·7356	4394·578	·286	·708	48·29
70·8231	4558·233	·827	·594	39·09	54·7592	4385·023	·548	·525	35·91
70·0485	4549·036	·766	·730	48·11	54·5710	4383·196	·720	·524	35·84
70·0971	4549·815	....	....	....	54·6253	4383·661	....	....	....
68·7370	4533·662	·139	·677	44·82	51·2352	4351·473	·006	·533	36·73
68·3175	4528·950	....	....	....	50·0081	4340·114	·634	·520	35·93
67·7530	4522·286	·855	·569	37·72	48·4513	4325·834	....	....	....
65·3137	4494·842	....	....	....	46·3656	4307·350	·081	·731	50·88
64·9741	4490·965	·621	·656	43·76	45·4886	4299·660	·211	·551	38·40
64·7682	4488·692	·259	·567	37·88	43·5033	4282·447	....	....	....
64·0446	4480·744	·400	·656	43·89	40·9840	4261·430	·640	·790	[+ 55·62]
63·6258	4476·259	....	....	....	40·8233	4260·100	·640	·540	38·02
58·0173	4417·346	·038	·692	46·99	40·8877	4260·492	....	....	....
57·9135	4416·295	985	·690	46·85	37·4506	4232·811	·328	·517	36·60
57·7454	4414·593	·293	·700	47·53	35·2002	4215·168	·668	·500	— 35·56
56·7800	4404·887	....	....	....	33·5100	4201·924	....	....	....
56·8555	4405·680	·927	·753	[+ 51·28]					

Mean............................		—42·81
V_a	+ 8·73	
V_d	+ ·16	
Curvature......................		— ·50
Radial velocity..................		—34·4

η VIRGINIS 658.

1907. Mar. 8.
G. M. T. 19h 33m

Observed by } J. S. Plaskett.
Measured by }

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
72·9340	4584·226	......	......	....		4351·298	·006	·708	48·78
72·8491	4583 000	·018	1·018	— 66·37	51·2078	4339·967	·634	·667	46·09
70·0825	4549·738	....	....	....	49·9833	4325·842	....	....	....
70·0187	4548·865	·766	·901	59 10	48·4411	4308·861	·081	·780	[+53·98]
68·3025	4528·878	....	....	....	46·5271	4307·400	·081	·681	47·40
65·2981	4494·769	....	....	....	46·3616	4307·992	....	....	....
64·0112	4480·620	·400	·780	52·18	46·4396	4299·365	·211	·846	58·97
63·6150	4476·242	....	....	....	45·4434	4293 582	·286	·704	49·14
62·8675	4468 118	·663	·545	36·57	44·7767	4261·248	·640	·608	[+42·70]
57·7336	4414·587	·293	·706	47 94	40·9524	4260·039	·640	·601	42·31
56·7695	4404·882	....	....	....	40·8062	4260·522	....	....	....
56·7001	4404·234	927	·693	47·19	40·8792	4232·720	328	·6(8	—43·05
54·5250	4382·847	·720	·873	59·71	37·4332	4201·970	....	....	....
54·6150	4383·661	....	....	....	33·5028				

Mean.............. . . ..— 50·34
V_a ....+ 8·66
V_d . . . .— ·11
Curvature ....— ·50

Radial velocity....... ....— 42·3

η VIRGINIS 663.

1907. March 11.
G. M. T. 16h 22m

Observed by } J. S. Plaskett.
Measured by }

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
72·9560	4' 84·034	....	....	....	53·6481	4374·448	·103	·655	44·93
72·9015	4583·350	·018	·668	−43·55	49·9837	4340·084	·634	·550	38·00
70·0476	4548·950	·766	·816	53·53	48·4276	4325·918	....	....	....
70·0966	4549 535	....	....	....	48·3513	4325·251	·939	·688	47·68
68·7283	4543·480	·139	·659	43·56	46·3495	4307·460	·081	·621	43·22
68·3248	4528·820	....	....	....	46·4206	4308·061	....	....	....
67·7359	4522·024	·855	·831	55·09	15·4650	4299·730	·211	·481	33·57
65·8590	4500·774	·448	·674	44·89	44·7810	4293·800	·273	·473	33·02
65·3158	4494·742	....	....	....	44·3135	4289·780	·377	·597	41·73
64·0407	4480 687	·400	·713	47·70	42·3240	4272·890	·482	·592	41·38
63·6289	4476·226	....	....	....	42·1426	4271·220	·934	·714	49·91
62·8520	4467·805	·663	·858	57·57	40·9262	4261·250	640	·610	(+42·94)
56·8198	4405·430	·927	·503	(+34·25)	40·7890	4260·120	·640	·520	36·61
56·7688	4404·881	....	....	....	40·8534	4260·658	....	....	....
54·7205	4384·790	·548	·758	51·85	37·4056	4232·760	328	·568	40·21
54·5417	4383·060	·720	·660	45·14	35·1485	4215·060	·668	·608	−43·05
54·6087	4383 658	....	....	....	33·4655	4202·164	....	....	....

Mean ... . −44·25
V_a .... +7·22
V_d . . .. + ·14
Curvature .... − ·59

Radial velocity. .... −37·4

η VIRGINIS 664.

1907. March 11. G. M. T. $19^h\ 05^m$

Observed by / Measured by J. S. PLASKETT.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement	Velocity.
72·9515	4583·979	....	....	....	56·2301	4399·532	·935	·403	27·48
72·9212	4583·645	018	373	24·32	55·7459	4394·749	286	537	36·62
71·9285	4571·520	156	636	41·72	54·7514	4385·020	548	·528	36·01
71·2620	4563·470	939	469	30·77	54·5660	4383·220	720	500	34·10
70·0711	4549·265	766	·501	32·98	54·6180	4383·745	....	....	....
70·1014	4549·592	....	....	....	51·2308	4351·534	006	·472	32·52
68·7499	4543·778	139	·361	23·90	48·4367	4326·000	....	....	....
68·3199	4528·764	....	....	....	46·3836	4307·679	081	402	27·98
67·1052	4514·874	·508	·634	42·10	46·4296	4308·143	....	....	....
65·8844	4501·099	·448	·349	23·28	45·4915	4299·875	·211	·336	23·45
65·3052	4494·624	....	....	....	45·0790	4296·295	·761	·462	32·25
64·0522	4480·842	·400	·558	37·40	44·7972	4293·850	241	·391	27·29
63·6294	4476·224	....	....	....	40·8615	4260·725	....	....	....
56·7130	4404·321	927	·606	41·27	35·1946	4215·340	668	328	—23·32
56·7745	4404·939	....	....	....	33·4760	4202·224	....	....	....

Mean	—31·50
V_a	+ 7·17
V_d	— ·09
Curvature	— ·50
Radial velocity	—24·9

η VIRGINIS 668.

1907. March 20. G. M. T. $15^h\ 43^m$

Observed by / Measured by J. S. PLASKETT.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9307	4584·286	....	....	....	54·6192	4383·822	·720	·102	+ 6·98
72·9280	4583·996	·018	·022	− 1·43	54·6085	4383·698	....	....	....
71·9823	4572·435	·156	·279	+18·30	51·2747	4351·980	·006	·026	− 1·79
70·8415	4558·702	827	·125	− 8·22	50·0492	4340·630	·634	004	− 0·27
70·6417	4556·316	·306	·010	+ 0·66	48·4396	4325·972	·939	·033	+ 2·29
70·0832	4549·686	766	·080	− 5·27	48·4360	4325·896	....	....	....
70·0791	4549·799	....	....	....	46·4305	4308·078	·081	·003	− 0·21
68·7612	4534·154	·139	015	+ 0·99	46·4307	4308·014	....	....	....
68·2992	4528·937	....	....	....	45·9036	4303·453	·503	·050	− 3·48
67·7907	4522·935	·855	080	+ 5·30	45·5332	4300·216	·211	·005	+ 0·35
65·2940	4494·823	....	....	....	45·1340	4296·742	·761	·019	− 1·33
64·0849	4481·373	·400	·027	− 1·81	44·8508	4294·290	·286	·004	+ 0·28
63·6111	4476·299	....	....	....	44·1324	4288·105	·129	·024	− 1·68
60·6976	4444·163	·976	193	+13·05	40·8648	4260·600	·640	·040	− 2·82
58·0730	4418·083	·038	·047	+ 3·19	40·8699	4260·545	....	....	....
57·8009	4415·330	·293	·037	+ 2·51	37·5322	4233·603	·594	·009	+ 0·64
56·7605	4404·881	·927	041	+ 2·79	35·2560	4216·373	·351	·022	+ 1·56
56·7651	4404·938	....	....	....	33·5024	4202·250	·198	·052	+ 3·71
55·7895	4395·262	·286	024	− 1·64	33·4954	4202·013	....	....	....

Mean	+1·00
V_a	+2·64
V_d	+ ·12
Curvature	− ·50
Radial velocity	+3·3

η VIRGINIS 671.

1907. March 20.
G. M. T. $19^h\ 36^m$

Observed by J. S. PLASKETT.
Measured by N. B. MCLEAN.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9325	4584·273	......	......	......	51·2977	4352·191	·006	·185	12·75
72·9571	4584·357	·018	·339	+ 22·17	48·4334	4325·847	......	......	......
70·1095	4549·966	·766	·200	13·18	46·4312	4307·993	......	......	......
70·0790	4549·763	......	......	......	46·4506	4308·264	·081	·183	12·74
68·7671	4534·480	·139	·341	22·54	44·8953	4294·698	·273	·425	29·66
68·3050	4528·973	......	......	......	44·8507	4294·192	......	......	......
67·1688	4515·794	·508	·286	18·99	37·5183	4233·518	·328	·190	12·74
65·2975	4494·831	......	......	......	36·7753	4227·435	......	......	......
64·0993	4481·512	·400	·112	7·49	35·2586	4215·768	·668	·100	+ 7·11
63·6115	4476·273	......	......	......	33·4896	4201·948	......	......	......
56·7679	4404·938	......	......	......					

Mean..........		+15·94
V_a..........		+ 2·56
V_d......	− ·17	
Curvature.	− ·50	
Radial velocity......		+ 17·8

η VIRGINIS 671.*

1907. March 20.
G. M. T. $19^h\ 36^m$

Observed by / Measured by } J. S. PLASKETT.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9357	4584·117	......	......	......	54·6192	4383·742	·720	·022	1·50
72·9454	4584·127	·018	·109	−7·11	54·6187	4383·825	......	......	......
70·1102	4549·924	·766	·158	10·41	51·3052	4352·212	·006	·206	14·19
70·0852	4549·684	......	......	......	48·4524	4326·040	·939	·101	7·07
68·7818	4534·322	·139	·183	12·10	48·4412	4326·041	......	......	......
68·3057	4528·855	......	......	......	46·4454	4308·142	·081	·061	4·24
67·1606	4515·652	·508	·144	9·56	46·4368	4308·221	......	......	......
65·3031	4494·811	......	......	......	40·8805	4260·680	·640	·040	2·82
64·1040	4481·520	·400	·120	8·03	40·8762	4260·771	......	......	......
63·6173	4476·280	......	......	......	37·5236	4233·490	·328	·162	11·45
57·8165	4415·416	·293	·123	8·35	35·2637	4215·741	·668	·073	+5·19
56·7841	4405·054	·927	·127	8·40	33·4936	4202·238	......	......	......
56·7689	4404·979	......	......	......					

Mean..................		+ 7·87
V_a..................		+ 2·56
V_d.........	− 0·17	
Curvature...	− 0·50	
Radial velocity..........		+ 9·8

*Check measurement. : +12·0 accepted as result.

η VIRGINIS 675.

1907. March 28.
G. M. T. 14h 05m

Observed by W. E. Harper.
Measured by J. S. Plaskett.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
72·9778	4584·134	......	......	......	56·7710	4404·957	......	......	......
73·0001	4584·288	018	·170	+11·08	54·8227	4385·770	·548	·222	15·18
72·0180	4572·321	156	·165	10·82	54·6327	4383·920	720	·200	13·68
71·3500	4564·238	939	·299	19·64	54·6122	4383·760	......	......	......
70·6728	4556·179	·030	·149	9·80	52·9684	4367·964	·841	·123	8·45
70·1407	4549·877	·766	·111	7·31	51·2952	4352·230	......	......	......
70·1170	4549·667	......	......	......	48·4190	4325·930	......	......	......
68·8290	4534·498	·139	·359	23·73	48·4376	4326·079	·939	·140	9·70
68·3370	4528·883	......	......	......	46·4296	4308·235	·081	·154	10·72
67·8353	4523·040	·855	·185	12·27	46·4120	4308·081	......	......	......
65·3222	4494·782	......	......	......	40·8766	4260·988	·640	·348	24·50
64·1318	4481·695	·400	·295	19·71	37·4956	4233·635	328	·307	21·74
63·6320	4476·242	......	......	......	35·2312	4215·870	·668	202	14·36
56·7882	4405·098	·927	·171	11·64	33·4357	4202·105	......	......	......

Mean	+14·43
V_a	−1·31
V_d	+ 0·22
Curvature	− 0·50
Radial velocity	+12·8

η VIRGINIS 689.

1907. April 3.
G. M. T. 15h 10m

Observed by / Measured by J. S. Plaskett.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9649	4584·144	......	......	......	54·6258	4383·844	·720	·124	8·27
70·1340	4549·875	·766	·109	+ 7·14	54·6128	4383·698	......	......	......
70·1159	4549·764	......	......	......	51·2895	4352·166	·006	160	10·70
68·8212	4534·500	·139	·361	23·72	48·4234	4325·880	......	......	......
68·3261	4528·836	......	......	......	46·4446	4308·335	·081	·254	17·12
65·3175	4494·761	......	......	......	46·4160	4308·023	......	......	......
64·1263	4481·608	·400	·208	13·71	45·9125	4303·675	·503	·172	11·63
63·6300	4476·230	......	......	......	45·5570	4300·575	·211	·364	24·64
56·8090	4405·284	·927	·357	23·60	44·8586	4294·511	·273	·238	16·18
56·7731	4404·924	......	......	......	40·8698	4260·872	640	·232	+15·87
55·8058	4395·362	·286	·076	5·05	40·8417	4260·561	......	......	......

Mean	+ 14·80
V_a	− 4·51
V_d	− ·11
Curvature	·50
Radial velocity	+ 9·9

η VIRGINIS 690.

1907. April 3.
G. M. T. $16^h\ 17^m$

Observed by / Measured by } J. S. Plaskett.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
72·9592	4584·173	......	......	......	56·7639	4404·932	......	......	......
72·9960	4584·471	·018	·453	+ 29·55	55·8482	4395·857	·286	·571	38·94
71·0286	4560·617	·233	·384	25·12	50·0825	4341·042	·634	·408	28·19
70·1388	4550·033	·766	·267	17·60	48·4841	4326·503	·939	·564	39·08
70·1069	4549·758	......	......	......	48·4215	4325·963	......	......	......
68·3186	4528·848	......	......	......	47·2800	4315·750	·255	·495	34·44
65·3118	4494·798	......	......	......	47·1651	4314·732	255	·523	[– 36·35]
64·1427	4481·855	·400	·455	30·43	46·4111	4308·081	......	......	......
63·6230	4476·255	......	......	......	45·9200	4303·775	·337	·438	30·53
57·8479	4415·778	·293	·485	32·93	44·1608	4288·550	·129	·421	29·43
56·8081	4405·367	·927	·440	30·24	40·8736	4260·916	·640	·276	+ 19·01
56·6936	4404·227	·927	·700	– 47·67]	40·8402	4260·648	......	......	......

Mean..................................		+ 29·65
V_a..................	– 4·55	
V_d..................................		+ ·03
Curvature..........	– ·50	
Radial velocity..................		+ 24·6

η VIRGINIS 697.

1907 April 5.
G. M. T. $15^h\ 58^m$.

Observed by / Measured by } J. S. Plaskett.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9470	4583·923	......	......	......	54·6175	4383·744	......	......	......
70·9202	4559·402	·827	·575	+37·60	51·3312	4352·463	·006	·457	31·53
70 1463	4550·179	·766	·413	27·05	50·1042	4341·108	·634	·474	32·75
70·1012	4549·590	......	......	......	48·4357	4325·987	......	......	......
68·8295	4534·710	·139	·570	37·80	47·2927	4315·705	·255	·450	31·27
68·3217	4528·784	......	......	......	47·1937	4314·826	·255	·429	[–29·81]
65·3176	4494·762	......	......	......	46·4779	4308·496	·081	·415	28·88
64·1482	4481·880	·400	·480	32·11	46·4326	4308·169	......	......	......
63·6242	4476·167	......	......	......	45·5922	4300·740	·211	529	36·92
56·8127	4405·284	·927	·643	43·79	44·8984	4294·722	·273	·449	31·34
56 7772	4404·965	......	......	......	37·5545	4233·854	·328	·626	44·32
55·8460	4395·709	·286	·423	28·97	33·5356	4202·602	·198	·401	+29·80
51·6681	4384·296	·720	·576	39·46	33·4808	4202·281	......	......	......

Mean..........................		+35·57
V_a...........	–5·53	
V_d..................		+ ·04
Curvature	— ·50	
Radial velocity...........		+29·6

η VIRGINIS 700.

1907. April 5.
G. M. T. $19^h\ 25^m$

Observed by J. S. PLASKETT.
Measured by N. B. MCLEAN.

Mean of Settings.	Measured Wave Length	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9795	4584·007	......	......	....	47·2780	4315·199	·178	·021	1·46
70·6955	4556·376	·202	·174	−11·45	46·4723	4308·062	......	......	....
70·1586	4549·999	·766	·233	15·35	45·6324	4300·696	·211	·485	33·80
67·8734	4523·349	·855	·494	32·75	44·8952	4294·300	......	......	....
67·2244	4515·934	·508	·426	32·80	44·4880	4290·792	·432	·360	25·16
65·3385	4494·673	......	......	....	43·5241	4282·526	......	......	....
64·1583	4481·666	·400	·266	17·80	39·2956	4247·432	·996	·436	30·78
56·8578	4405·406	·927	479	32·57	37·5965	4233·782	·328	·454	32·15
56·8097	4404·919	......	......	....	34·6504	4210·711	·494	·217	15·45
54·6545	4383·717	......	......	....	34·4688	4209·318	·766	552	+39·30
50·1316	4340·992	634	·358	24·74	33·5334	4202·086	......	......	....

Mean.......... ...	+24·67
V_a	−5·61
V_d	− ·04
Curvature.......	− ·50
Radial velocity......	+18·5

η VIRGINIS 706.

1907. April 11.
G. M. T. $17^h\ 13^m$

Observed by W. E. HARPER.
Measured by N. B. MCLEAN.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
73·0252	4584·009	....	....	....	54·6829	4383·697	....	....	....
73·0563	4584·400	·018	·382	+24·91	51·3729	4352·266	·006	·260	17·91
70·2033	4549·936	·766	·170	11·21	50·1578	4341·034	·634	·400	27·64
70·1766	4549·650	....	....	....	48·4969	4325·852	....	....	....
68·8928	4534·539	·139	·400	26·44	46·5327	4308·461	·081	·380	26·45
68·3993	4528·874	....	....	....	46·4914	4308·038	....	....	....
66·0257	4501·812	·448	·364	24·24	44·5012	4290·688	·273	·415	28·97
64·2117	4481·744	·400	·344	23·01	40·9230	4260·593	....	....	....
63·7004	4476·242	....	....	....	39·3010	4247·386	·996	·390	27·53
56·8923	4405·417	·927	·490	26·52	37·6057	4233·788	·328	·460	32·57
56·8424	4404·920	....	....	....	36·7918	4227·354	·904	·450	31·90
56·7860	4404·357	·927	570	[−38·76]	35·4373	4216·072	·668	·404	+28·72
55·9167	4395·766	·286	·480	25·92	33·5337	4202·043	....	....	....

Mean	+25·60
V_a	−8·51
V_d	− ·10
Curvature	− ·50
Radial velocity......	+16·5

η VIRGINIS 707.

1907. April 11.
G. M. T. 18h 07m

Observed by W. E. HARPER.
Measured by N. B. MCLEAN.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9643	4583·714	.....	.....	.....	51·3304	4352·509	·006	503	34·66
70·1047	4549·274	.....	.....	.....	50·0992	4341·122	·634	·488	33·72
68·8355	4534·747	·139	·608	+40·19	48·4287	4326·034	.....	.....	.....
68·3225	4528·477	.....	.....	.....	46·4243	4308·243	.....	.....	.....
67·8441	4523·290	·974	316	20·95	44·8994	4294·832	·273	559	39·02
65·3154	4494·487	.....	.....	.....	44·8392	4294·466	.....	.....	.....
64·1454	4481·832	·400	·432	28·90	40·8493	4260·880	.....	.....	.....
63·6286	4476·002	.....	.....	.....	35·2821	4216·174	·668	·506	+35·98
56·7723	4404·850	.....	.....	.....	33·4581	4202·503	.....	.....	.....
54·6722	4384·277	720	·557	38·10					

Mean........		+ 33·94
V_a	− 8·51	
V_d	− ·16	
Curvature.....	·50	
Radial velocity..		+ 24·8

η VIRGINIS 710.

1907. Apr. 15.
G. M. T. 13h 52m

Observed by J. S. PLASKETT.
Measured by N. B. MCLEAN.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9756	4584·259	·018	·285	+18·58	54·5966	4383·764	.....	.....	.....
72·9562	4584·064	.....	.....	.....	51·2851	4352·306	006	·500	20·67
70·1322	4550·046	·766	·280	18·45	50·0696	4341·083	634	·449	31·02
70·0986	4549·632	.....	.....	.....	48·4016	4325·934	.....	.....	.....
68·8294	4534·780	·139	·641	42·37	47·2672	4315·797	·255	·542	37·18
68·3115	4528·765	.....	.....	.....	46·3939	4308·085	.....	.....	.....
64·1287	4481·791	·400	·391	26·15	40·8240	4260·680	.....	.....	.....
63·6156	4476·226	.....	.....	.....	35·2488	4216·152	·668	·484	+34·41
62·9515	4469·024	·663	·361	24·42	33·4250	4202·121	.....	.....	.....
56·7555	4404·958	.....	.....	.....					

Mean......		−28·36
V_a	−10·37	
V_d		+ ·14
Curvature.....	— ·59	
Radial velocity...		−17·6

η VIRGINIS 715.

1907. April 18. G. M. T. 13h 07m

Observed by W. E. HARPER. Measured by N. B. McLEAN.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
73·0413	4583·808				54·7087	4383·732			
70·2330	4550·099	766	333	+21·94	48·5285	4326·037			
70·1937	4549·475				46·5245	4308·221			
68·9173	4534·656	139	·517	34·17	45·6859	4300·737	·081	·656	45·72
68·4144	4528·686				44·9433	4294·456			
65·4041	4494·618				40·9521	4260·802			
64·2393	4481·871	·400	·471	31·51	37·6396	4233·929	·328	601	+42·55
56·8673	4404·927				33·5617	4202·331			
54·9478	4386·040	·548	·492	33·65					

Mean		+34·92
V_a	11·83	
V_d		+ ·12
Curvature	− ·50	
Radial velocity		+22·7

η VIRGINIS 722.

1907. April 18. G. M. T. 16h 25m

Observed by W. E. HARPER. Measured by N. B. McLEAN.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
72·9273	4583·916				57·9653	4417·166	·985	181	12·29
71·9864	4572·502	156	·346	+ 22·70	56·7445	4404·927			
70·1087	4549·974	·766	·208	13·71	50·0411	4340·871	·634	·237	16·38
70·0793	4549·574				48·4003	4325·989			
68·3004	4528·789				43·4360	4282·607			
65·2903	4494·718				40·8143	4260·678			
64·1017	4481·642	·400	·242	16·19	37·4789	4233·651	·328	·323	+ 22·87
63·6110	4476·289				33·4294	4202·259			

Mean		+ 17·36
V_a	− 11·83	
V_d	− ·16	
Curvature	− ·50	
Radial velocity		+ 4·9

η VIRGINIS 722.*

1907. April 18.
G. M. T. 16h 25m.

Observed by } W. E. Harper.
Measured by }

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
70·1299	4549·969	·766	·203	+13·38	56·7685	4404·997	·927	·070	4·77
70·0937	4549·227	......	......	......	56·7614	4404·950	......	......	......
68·7838	4534·291	·139	·157	10·38	50·0566	4340·893	·634	·259	14·70
65·3070	4494·531	......	......	......	48·4118	4326·137	......	......	......
64·1147	4481·547	·400	·147	9·83	48·4383	4326·177	·939	·238	16·49
63·6260	4476·126	......	......	......	46·4327	4308·320	·081	·239	+16·70

Mean........................		+11·84
V_a	−11·83	......
V_d	− ·16	......
Curvature....	·50	......
Radial velocity...	− 0·6	......

* Check measurement: + 2 accepted as result.

η VIRGINIS 723.

1907. April 18.
G. M. T. 17h 57m

Observed by W. E. Harper.
Measured by N. B. McLean.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
73·0024	4584·404	·018	·386	+25·24	50·1038	4341·065	·634	·431	29·78
72·9705	4583·994	......	......	......	48·4397	4326·012	......	......	......
70·1535	4550·061	·766	·295	19·44	47·3011	4315·763	·255	·508	34·82
70·1204	4549·625	......	......	......	46·4301	4308·148	......	......	......
68·8313	4534·568	·139	·429	28·36	44·8928	4294·672	·273	·399	27·85
68·3309	4528·715	......	......	......	44·8485	4294·380	......	......	......
65·9716	4501·939	·448	·491	32·70	43·4794	4282·663	......	......	......
64·1510	4481·824	·400	·424	28·37	40·8601	4260·752	......	......	......
56·8119	4405·231	·927	·304	20·70	36·7279	4227·418	·021	·397	28·15
56·7813	4404·927	......	......	......	35·2742	4216·088	·668	·420	+29·86
54·6267	4383·771	......	......	......	33·4616	4202·224	......	......	......
51·3158	4352·273	·006	·227	15·64					

Mean....................		+26·74
V_a	−11·85	
V_d	− ·24	
Curvature ...	− ·50	
Radial velocity............		+14·2

η VIRGINIS 725.

1907 April 19.
G. M. T. 13h 19m.

Observed by J. S. PLASKETT.
Measured by N. B McLEAN.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9673	4584·018	...	...	...	54·6157	4383·714	...	...	...
72·9967	4584·378	·018	·360	+23·47	51·3238	4352·451	·006	·445	30·66
72·0482	4572·796	·156	·640	41·92	50·1015	4341·154	634	520	35·88
70·1663	4550·244	766	·478	30·97	48·4257	4325·932	...	...	...
70·1130	4549·597	...	...	...	47·9344	4321·510	·992	518	35·95
68·8427	4534·719	·139	580	38·34	46·4782	4308·600	081	·519	36·12
68·3352	4528·823	...	...	...	46·4207	4308·110	...	...	...
67·8487	4523·235	·855	·380	25·19	45·1786	4297·257	761	496	34·62
67·2263	4516·116	508	608	40·37	44·8859	4294·729	·273	·456	31·83
65·3221	4494·719	...	...	...	43·4654	4282·589	...	...	...
64·1620	4481·928	·400	·528	35·32	40·8422	4260·647	...	...	...
63·6368	4476·224	...	...	...	39·2184	4247·396	·996	400	28·24
56·8423	4405·585	·927	658	44·74	37·5362	4233·814	·328	·486	34·41
56·7762	4404·927	...	...	...	36·2807	4227·514	·904	610	+43·25
55·8375	4395·640	·286	·354	24·14	33·4474	4202·155	...	...	...

Mean.....		+34·19
V_a	12·22	
V_d		+ ·17
Curvature...	50	
Radial velocity...		+ 21·6

η VIRGINIS 728.

1907. April 19.
G. M. T. 15h 12m.

Observed by J. S. PLASKETT.
Measured by N. B. McLEAN.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9499	4584·202	...	...	...	54·5814	4383·696	...	...	...
70·1477	4550·385	·766	·619	+40·79	51·2893	4352·464	·006	·458	31·56
70·0854	4549·655	...	...	...	50·0690	4341·190	·634	556	38·42
68·8057	4534·638	139	499	32·98	48·4471	4326·456	939	·517	35·83
68·3004	4528·796	...	...	...	48·3888	4325·892	...	...	...
67·8300	4523·365	·855	510	33·81	47·0176	4313·699	·034	665	46·22
67·1722	4515·852	·508	344	22·84	46·3814	4308·049	...	...	...
65·2989	4492·822	...	...	...	44·8594	4294·836	·273	·563	39·30
64·1192	4481·811	400	·411	27·50	44·7978	4294·267	...	...	...
62·9397	4469·020	663	·357	23·95	40·8055	4260·612	...	...	...
60·6358	4444·510	·976	534	36·04	37·5116	4234·011	328	683	48·35
56·8096	4405·581	·927	654	44·54	35·2493	4216·278	668	610	+ 43·38
56·7438	4404·927	...	...	...	33·4070	4202·093	...	...	...

Mean................. .		+36·37
V_a	−12·26	
V_d		+ ·02
Curvature...........	− ·50	
Radial velocity.. ...		+23·6

η VIRGINIS 729.

1907. April 19.
G. M. T. 16h 02m

Observed by J. S. Plaskett.
Measured by N. B. McLean.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
72·9587	4584·013				68·3198	4528·740			
72·0028	4572·356	·156	·200	+13·12	65·3089	4494·664			
71·3442	4564·407	·939	·468	30·75	64·1332	4481·759	400	·359	+24·02
70·1502	4550·179	766	·413	27·22	63·6253	4476·188			
70·1032	4549·579				56·7680	4404·927			
68·8224	4534·619	139	·480	31·73	40·8339	4260·646			

Mean	+25·78
V_a	−12·29
V_d	− ·04
Curvature	− ·50
Radial velocity	+13·0

η VIRGINIS 730.

1907. April 19.
G. M. T. 17h 50m

Observed by J. S. Plaskett.
Measured by N. B. McLean.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
72·9837	4584·121				56·7842	4404·927			
70·1866	4550·350	·766	·584	+38·49	50·1312	4341·364	·634	·730	50·44
70·1261	4549·657				48·5071	4326·623	·939	·684	47·40
68·3413	4528·801				48·4332	4325·928			
67·2666	4516·481	·508	·973	64·61	46·4196	4308·030			
65·3326	4494·747				40·8505	4260·650			
64·1822	4482·074	·400	·674	45·09	37·5470	4233·942	·328	·614	+43·47
63·6521	4476·303				33·4532	4202·138			

Mean	+46·39
V_a	−12·31
V_d	− ·17
Curvature	− ·50
Radial velocity	+33·4

η VIRGINIS 735.

1907. April 24.
G. M. T. $14^h\ 03^m$

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
73·4020	4588·733	·381	·352	+22·95	56·8059	4404·873	......	......	......
73·0530	4584·430	·018	·412	26·94	55·8631	4395·608	·286	322	21·96
73·0195	4584·023	......	......	......	54·6456	4383 671	......	......	......
70·1890	4549·943	·766	·177	11·66	51·3431	4352·412	006	·406	27·97
70·1620	4549·608	......	......	......	47·9577	4321·563	·992	·571	39·57
68·8716	4534 521	·139	·382	25·25	46·4768	4308·268	·081	187	12·50
68·3750	4528·752	......	......	......	46·4355	4307·956	......	......	......
67·8740	4523·016	·855	·161	10·01	40·9017	4261·041	·640	·401	28·23
66·0020	4501·835	·448	·387	25·77	40·8580	4260·561	......	......	......
65·3651	4494·721	......	......	......	37·5298	4233·800	·328	·472	33·43
64·1840	4481·755	·400	·355	23·75	35·2690	4216·089	·668	·421	+29·97
63·6714	4476 154	......	......	......	33·4569	4202·034	......	......	......
56·8306	4405·170	·927	243	16·55					

Mean		21·55
V	14 50	
$V_{?}$		·09
Curvature..........	·50	
Radial velocity...........		6·6

η VIRGINIS 737.

1907. Apr. 24.
G. M. T. $15^h\ 25^m$

Observed by J. S. Plaskett.
Measured by N. B. McLean.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
73·0344	4584·252	......	......	......	54·6567	4383·665	......	......	......
72·0830	4572·435	156	·279	+18·27	51·3386	4352·251	·006	245	16·88
70·2079	4550·026	766	·260	17·13	48·4585	4325·791	......	......	......
70·1753	4549·781	......	......	......	46·4978	4308·517	·081	436	30·34
68·3884	4528·904	......	......	......	46·4490	4307·923	......	......	......
64·2125	4481·940	·400	·540	36·13	42·2980	4272·508	·760	·748	+52·51
63·6839	4476·243	......	......	......	42·1963	4271 660	·760	·100	[− 7·02]
56·8200	4404·909	......	......	......	40·8687	4260·425	......	......	......
55·8670	4395·510	·286	·224	15·28					

Mean..............................		−26·65
V_a	—14·50	
V_d	— ·02	
Curvature..........	— ·50	
Radial velocity....................		+11.6

η VIRGINIS 738.

1907. April 26.
G. M. T. 16h 20m

Observed by J. S. PLASKETT.
Measured by N. B. McLEAN.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9932	4584·254	018	·236	+15·39	63·6467	4476·189	...	....	....
72·9740	4583·970	......	...	....	56·8273	4405·316	·927	·389	26·45
70·1509	4550·011	766	·245	16·15	56·7879	4404·971	....	...	......
70·1180	4549·552	......	...	....	50·1028	4341·021	·634	·387	26·74
68·8416	4534·661	139	·522	34·50	48·4143	4326·009	....	......	.....
68·3345	4528·721	.....	......	....	35·7289	4219·538	.	...	....
67·8650	4523·375	855	·520	34·48	35·2678	4215·938	·668	·270	+19·20
65·3336	4494·765	.....	...	....	33·4759	4202·199	......	......	....
64·1513	4481·740	·400	·340	22·75					

Mean .... +24·46
V_a .... −15·38
V_d .... − ·11
Curvature .... − ·50

Radial velocity .... + 8·5

η VIRGINIS 740.

1907. April 27.
G. M. T. 16h 10m

Observed by J. S. PLASKETT.
Measured by N. B. McLEAN.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
72·9961	4584·101	......	......	....	51·3341	4352·388	·006	·382	26·32
72·0653	4572·679	·156	·523	+ 34·31	50·1063	4341·049	·634	·415	28·68
70·1788	4550·094	·766	·328	21·62	48·4782	4326·219	·939	280	19·40
68·8587	4534·628	·139	·489	32·32	48·4440	4325·861	....	....	....
68·3549	4528·812	....	....	....	46·4694	4308·365	·081	·284	19·77
67·8736	4523·258	·855	·403	26·72	44·8795	4294·571	·273	·298	20·80
67·2342	4515·957	·508	·449	29·81	44·8482	4294·171	....	....	....
65·3458	4494·758	....	....	....	37·5356	4233·800	·328	472	33·42
64·1676	4481·778	·400	·378	25·29	36·7527	4227·414	....	....	....
63·6566	4476·325	....	....	....	35·2891	4216·215	·668	·547	+ 38·89
56·8341	4405·271	·927	·344	23·39	33·4568	4201·909	....	....	....
56·7958	4404·905	....	....	...					

Mean........................ + 27·20
V_a .... 15·80
V_d .... ·10
Curvature .... − ·50

Radial velocity.............. + 10·8

η VIRGINIS 742.

1907. May 2.
G. M. T. 13h 22m.

Observed by W. E Harper.
Measured by N. B. McLean.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72·9620	4584·009	......	......	......	67·8535	4523·440	·855	·585	38·78
70·1570	4550·259	·766	·493	+32·49	65·3062	4494·683	......	......	......
70·1027	4549·570	......	......	......	64·1340	4481·814	·400	·414	27·70
69·4723	4542·201	·690	·511	33·73	62·9622	4469·109	·663	·446	+29·93
68·8251	4534·654	139	·514	33·97	56·7616	4404·974	......	......	......
68·3217	4528·782	......	......	......					

Mean..................		+32·77
V_a..........	17·80	......
V_d..................		+ ·12
Curvature......	·50	......
Radial velocity........		14·6

η VIRGINIS 742*

1907. May 2.
G. M. T. 13h 22m

Observed by }
Measured by } W. E. Harper.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
71·1942	4550·274	766	·508	+33·48	65·1712	4481·843	·400	·443	29·64
71·1408	4549·664	......	......	......	63·9916	4469·074	663	411	27·58
69·8567	4534·624	·139	485	32·06	63·7725	4466·734	......	......	......
69·3531	4528·797	......	......	......	46·1631	4297·293	·861	432	30·15
68·8787	4523·325	·855	·470	31·11	45·8362	4294·269	......	......	......
66·3483	4494·817	......	......	......					

Mean..................		+30·67
V_a........	−17·80	
V_d..................		+ ·12
Curvature .	− ·50	
Radial velocity..........		+12·5

* Check measurement: the mean of the two measurements, +13·5, used.

η VIRGINIS 748.

1907. May 4.
G. M. T. 16^h 27^m

Observed by J. S. PLASKETT.
Measured by N. B. McLEAN.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement	Velocity.
73·0098	4584·081	......	......	......	54·6824	4383·758	......	......	......
68·8588	4534·429	139	·290	+19·17	46·4974	4308·126	......	......	......
68·3712	4528·741	......	......	......	45 9942	4303·634	337	·297	20·49
64·8913	4489·419	258	·161	10·75	45·5125	4299·508	......	......	......
64·1808	4481·603	400	203	13·58	37·9108	4236·170	......	......	......
63·6888	4476·254	......	......	......	37·5937	4233·569	·328	·241	17 06
56·8664	4405·231	927	304	20·67	35·8133	4219·623	......	......	......
56·8352	4404·927	......	......	......	35·3564	4215·997	·668	329	-23 39
55 8807	4395 460	·286	·174	·11·87	33·5589	4202·259	......	......	......

Mean........		+17 12
V_a	18·64	
V_d	− ·15	
Curvature	− ·50	
Radial velocity........	− 2·2	

η VIRGINIS 751.

1907. May 7.
G. M. T. 13^h 32^m

Observed by W. E. HARPER.
Measured by N. B. McLEAN.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
73·0992	4584·317	·018	299	+19·49	55·8200	4395·554	·286	·268	18·28
72·9749	4584·024	......	......	......	54·6325	4383·971	·720	251	17·17
70·1475	4549·956	766	·190	12·52	54·6052	4383·706	......	......	......
68 8403	4534·641	·139	·502	33·18	50·0804	4341·094	·634	·460	31·79
68·3355	4528·798	......	......	......	48·4210	4326·034	939	095	6·58
67·8631	4523·365	855	·510	33·81	46·4297	4308·241	·081	160	11·14
65·9582	4501·800	·448	·352	23·44	46·3983	4308·053	......	......	......
65·3236	4494·752	......	......	......	45·5256	4300·440	211	·229	15·96
64·1351	4481·660	·400	·260	17·39	44·8198	4294·323	......	......	......
63·6380	4476·258	......	......	......	42·2118	4272·177	934	·243	17·06
60·6275	4444·222	·976	·246	16·60	40·8218	4260·640	......	......	......
56·8231	4405·472	·927	·545	37·06	35·2347	4216·038	·668	·370	+26·31
56·7683	4404·927	......	......	......	33·4168	4202·180	......	......	......

Mean........		+19·98
V_a	−19·72	
V_d		+ ·04
Curvature........	− ·50	
Radial velocity........	− 0·2	

η VIRGINIS 754.

1907. May 9.
G. M. T. 13h 30m

Observed by W. E. Harper.
Measured by N. B. McLean.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
72 9904	4584·037				62 7514	4466·739			
70 1663	4550 168	766	332	+21·85	56 7613	4404 981			
68·8184	4534·337	139	·198	13·09	46·3866	4308·213	081	132	9 19
68 3378	4528·775				46·3754	4308 089			
66 7761	4508·699	·455	·244	16·25	44 3601	4290·622	·432	190	+13·28
65 2283	4494·794				40·7874	4260·643			
64 1314	4481·614	·400	·214	14·32					

Mean..................		+14·66
V_a	−20·45	
V_d		+ ·07
Curvature....	− ·50	
Radial velocity...	− 6·2	

η VIRGINIS 757.

1907. May 14.
G. M. T. 15h 12m

Observed by W. E. Harper.
Measured by N. B. McLean.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
78 1657	4594·216				56·4492	4452·156			
77·0834	4586·476				50·3683	4416 856	·985	·129	8 76
76 7190	4583·947	018	·071	−3·98	50·0908	4415 269			
76 2366	4580·472				48·2477	4404 927			
68·6518	4528·671				29·5592	4308·081			
67 7526	4522·847	·855	008	0·53	26·6367	4294·149	·273	·124	−8·66
63·3913	4494·710				26·6690	4294·294			
61·2339	4481 243	·400	·157	10·50					

Mean..................	− 6·49
V	−22 17
V_d	− ·11
Curvature............	− ·50
Radial velocity.....	29 3

η VIRGINIS 757.*

1907. May 14.
G. M. T. 15h 12m

Observed by W. E. HARPER.
Measured by J. S. PLASKETT.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
76·6347	4583·989	018	029	− 1·89	50·0070	4415·336	...	...	...
76·6343	4583·826	...	...	...	46·5463	4395·976	·286	689	[+46·99]
76·9997	4586·424	...	...	...	46·4122	4395·237	·286	·049	− 3·34
74·9497	4572·135	156	021	− 1·38	46·4407	4395·482	...	...	...
71·6953	4549·730	·766	036	− 2·37	44·6292	4385·509	548	·039	− 2·67
71·0828	4545·437	...	...	...	44·4397	4384·482	·720	762	[+52·12]
69·3866	4534·212	168	·044	+ 2·91	44·2474	4383·443	·720	277	−18·95
68·5673	4528·654	...	...	...	44·2977	4383·810	...	...	...
67·8573	4524·103	855	1·248	+[82·74]	38·2630	4351·874	·006	132	− 9·09
67·6547	4522·774	855	081	− 5·37	33·1184	4325·877	·939	·062	4·30
65·4297	4508·320	455	135	− 8·98	33·1323	4326·082	...	...	...
63·3016	4494·685	...	...	...	29·4489	4307·954	·081	127	− 8·84
62·7656	4491·371	·570	199	−13·29	27·6261	4299·235	·410	165	−11·50
61·1506	4481·283	·400	117	− 7·83	26·7665	4295·164	·273	891	[+62·19]
60·3275	4476·163	...	...	...	26·5533	4294·156	·273	117	− 8·17
54·9935	4444·063	·976	087	+ 5·87	26·5828	4294·428	...	...	...
54·6148	4441·859	...	...	...					

Weighted mean	6·00
V_a	−22·50
V_d	− ·11
Curvature	− ·28
Radial velocity	−28·9

* Check measurement.

η VIRGINIS 761.

1907. May 18.
G. M. T. 16h 05m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
74·9488	4572·070	156	086	− 5·62	61·1405	4481·265	·400	135	9·03
74·9323	4571·940	...	...	...	58·7736	4466·641	...	...	...
72·3285	4553·974	·211	237	15·57	49·2489	4411·068	·205	137	9·29
71·6942	4549·687	...	...	...	46·4223	4394·909	...	...	...
71·6790	4549·554	·766	·212	13·97	46·3646	4395·063	·286	·223	15·25
63·2955	4494·706	...	...	...					

Weighted mean	−11·35
V_a	−23·40
V_d	− ·00
Curvature	− ·28
Radial velocity	−35·0

η VIRGINIS 763.

1907. May 20.
G. M. T. 15h 07m

Observed by W. E. Harper.
Measured by N. B. McLean.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
79·8946	4594·216				51·8724	4415·266			
78·8148	4586·552				50·0330	4404·927			
73·5214	4549·697	766	069	4·50	45·3789	4379·438			
71·1940	4534·031	168	137	− 9·07	40·1355	4351·743	·006	·263	18·13
70·4030	4528·728				35·0304	4325·992			
69·5012	4522·833	·855	022	− 1·46	31·3760	4308·108			
69·1025	4520·219	397	178	11·81	28·9327	4296·365	·761	396	27·65
65·1443	4494·697				28·4542	4294·103	·273	·170	11·87
62·9966	4481·283	400	117	− 7·83	21·1660	4260·640			
60·6345	4466·712				21·1248	4260·455	640	185	− 13·03
51·8818	4415·341	293	048	+ 3·26					

Mean	− 10·21
V_a	− 24·00
V_d	− ·12
Curvature	− ·28
Radial velocity	− 34·6

η VIRGINIS 773.

1907. May 23.
G. M. T. 13h 36m

Observed by W. E. Harper.
Measured by N. B. McLean.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
72·9936	4864·545				43·0822	4308·047			
72·8570	4861·327	·527	200	− 12·32	42·5373	4300·114	·211	097	6·76
58·6518	4564·749				42·1351	4294·241			
57·8328	4549·666	·766	100	6·59	35·4807	4202·183			
56·6824	4528·829				35·4691	4202·042	198	·156	− 11·12
47·7827	4376·104				20·6201	4023·563			
44·2879	4325·892								

Mean	9·20
V_a	24·80
V_d	− ·03
Curvature	− 28
Radial velocity	− 34·3

η VIRGINIS 777.

1907. May 24.
G. M. T. 13ʰ 25ᵐ

Observed by J. S. Plaskett.
Measured by N. B. McLean.

Mean of Settings.	Corrected Star Settings.	Displacement in revns.	Velocity.	Mean of Settings.	Corrected Star Settings.	Displacement in revns.	Velocity.
73·0048	....	....	....	54·7557	....	....	....
72·8872	72·8468	0281	+ 40·82	53·9982	53·9698	·0132	15·23
60·2271	....	....	....	51·4108	51·3860	0128	14·34
59 8224	....	....	....	50·5182	....	....	....
57·8581	57·8225	·0178	21·48	48·7955	48·7747	·0107	+ 11·64
57·8352	....	....	....	48·7910	....	....	....
56·6806	....	....	....	44·2817	....	....	....

Mean..........................		+ 20·70
V_a.	− 25·13	
V_d.....	− ·02	
Curvature	− ·28	
Radial velocity...........	− 4·7	

η VIRGINIS 789.

1907. May 29.
G. M. T. 14ʰ 45ᵐ

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
73 2041	4871 453	....	....	....	52·6800	4460·462	....	....	....
72·8070	4862·067	527	540	+33·32	49·3193	4405·014	....	....	....
59·7478	4586·786	....	....	....	48·7302	4395·496	·286	·210	14·32
59·6227	4584·208	·018	190	12·39	45·2385	4341·270	....	....	....
58·5574	4564·299	·939	·360	23·62	43·0317	4308·246	·081	165	11·42
58·1392	4556·587	·202	·385	25 33	42·5029	4300·504	·211	293	20·30
57·7835	4550·056	·766	·290	19·11	42 0766	4294·384	....	....	....
57·7609	4549·855	....	....	....	40·5180	4271·967	·760	·207	14·50
56·9279	4534·529	·139	390	25·82	39·7122	4260·657	....	....	....
56·6078	4528 947	....	....	....	37·7766	4233·828	·328	500	35·40
55·0829	4501·748	448	300	19 90	36·4552	4215·948	·668	·280	19·91
54·6890	4494·977	....	....	....	35·4233	4202·198	....	....	....
53·9235	4481 640	·400	·240	16·06	29·6175	4128 302	862	·440	31 42
53·1959	4469 200	·668	·532	35·60	24·1875	4064·079	759	·320	22 91

Mean........		+23·26
V_a...	26 26	
V_d......	− ·16	
Curvature...........	− ·28	
Radial velocity..........	− 3	

η VIRGINIS 789.*

1907. May 29. G. M. T. 14h 45m.

Observed by J. S. Plaskett.
Measured by N. B. McLean.

Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
72·8699	.....	.....	.....	53·2538	53·2400	·0262	29·97
72·8630	72·8574	·0367	+53·32	49·3755	.....	.....	.....
72·4028	.....	.....	.....	48·7827	.....		.....
59·6769	59·6657	·0171	21·08	47·7691	.....	.....	.....
57·8398	57·8271	·0124	14·96	45·3031	45·2979	·0492	51·51
57·8117	.....	.....	.....	44·2755	.....	.....	.....
56·9991	56·9847	·0394	47·05	40·9177	.....	.....	.....
56·6622	.....	.....	.....	40·5689	40·5677	·0168	+16·72
55·1265	55·1121	·0030	3·51	39·7652	.....	.....	.....
53·9787	53·9651	·0085	9·81	35·4743	.....	.....	.....

Mean..................		+27·55
V_a	−26·26	
V_d	− ·16	
Curvature....	− ·28	
Radial velocity..........		+0·8

* Measured for trial of short method of reduction; result not used.

η VIRGINIS 795.

1907. May 31. G. M. T. 14h 06m.

Observed by J. S. Plaskett.
Measured by N. B. McLean.

Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
72·9422	.....	.....	.....	53·9722	53·9948	·0382	44·07
72·8177	72·8370	·0183	+26·59	51·7537	51·7785	·0289	32·51
60·1767	.....	.....	.....	49·3373	.....	.....	.....
59·7646	.....	.....	.....	48·7461	.....	.....	.....
57·8116	57·8284	·0237	28·59	45·2552	45·2876	·0389	+40·72
56·9534	56·9698	·0245	29·26	44·2407	.....	.....	.....
56·6308	.....	.....	.....	39·7275	.....	.....	.....
54·7038	.....	.....	.....	35·4363	.....	.....	.....

Weighted Mean..................		+34·40
V_a	−26·68	
V_d	− ·11	
Curvature........	− ·28	
Radial velocity..............		+7·3

η VIRGINIS 811.

1907. June 10.
G. M. T. $13^h\ 35^m$

Observed by J. S. Plaskett.
Measured by N. B. McLean.

Mean of Settings.	Corrected Star Settings.	Displacement in revns.	Velocity.	Mean of Settings.	Corrected Star Settings.	Displacement in revns.	Velocity.
72·9337				52·2473			
72·8114	72·8414	·0227	+32·98	48·7827			
72·3689				45·2927			
60·1912				45·3105	45·2985	·0498	52·14
59·7814				44·2834			
57·8175	57·8130	·0083	10·01	36·5500	36·5364	·0351	+33·50
56·6551				35·4900			
54·0050	53·9962	·0396	45·69	35·5658			

Weighted mean	+37·15
V_a	−28·31
V_d	— ·12
Curvature	— ·28
Radial velocity	+ 8·4

η VIRGINIS 822.

1907. June 11.
G. M. T. $13^h\ 28^m$

Observed by W. E. Harper.
Measured by N. B. McLean.

Mean of Settings.	Corrected Star Settings.	Displacement in revns.	Velocity.	Mean of Settings.	Corrected Star Settings.	Displacement in revns.	Velocity.
60·1977				52·2517			
59·7904				48·7796			
57·8416	57·8328	·0281	+33·90	44·3095	44·2991	·0268	+27·76
56·6525				44·2830			
54·0072	53·9972	·0406	+46·84				

Weighted mean	+36·17
V_a	−28·44
V_d	— ·12
Curvature	— ·28
Radia velocity	+ 7·3

η VIRGINIS 835.

1907. June 12.
G. M. T. 14ʰ 35ᵐ

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
71·8486	4550·456	766	690	45·47	63·3303	4494·789	......	....	......
71·7286	4549·267	..	....	..	61·3025	4482·094	·400	694	46·43
69·5323	4534·900	·139	·761	50·45	58·7945	4466·891	.. ...	....	....
68·6035	4528·549	...	....		55·1215	4444·790	976	814	+54·94
66·5610	4515·000	·508	·508	.	50·0100	4415·643	... ...	....	.....

Weighted mean...... ...... 48·52
V_a .... —28·46
V_d . ... - ·20
Curvature........ - ·28

Radial velocity. .... 19·6

η VIRGINIS 915.

1907. July 5.
G. M. T. 14ʰ 02ᵐ

Observed by J. S. PLASKETT.
Measured by N. B. MCLEAN.

Mean of Settings.	Corrected Star Settings.	Displacement in revns.	Velocity.	Mean of Settings.	Corrected Star Settings.	Displacement in revns.	Velocity.
60·2351	. .		. .	54·7528	. . . .	....	. . . .
59·8251	..	...	. ..	54·0197	53·9941	·0243	27·97
57·8818	57·8578	·0310	+37·32	52·2756	... .	....	
56·6911	. . .	...		49·4425	49·4125	·0451	+49·27
55·1902	55·1638	0386	45·02	48·8002	.	... ...	...

Mean........... .... 39·89
V_a . . . . -28·38
V_d . ... – ·25
Curvature. ...... — ·28

Radial velocity .... 11·0

SUMMARY OF MEASURES OF η VIRGINIS.

Plate Number.	Date.	G.M.T.	Julian Day.	Phase.	Velocity.	Plate Number.	Date.	G.M.T.	Julian Day.	Phase.	Velocity.
	1907.	h m					1907.	h m			
629	Feb. 22	17 57	2,417,629·75	0·75	− 4	728	Apr. 19	15 12	685·63	56·63	+27
638	" 25	18 50	632·78	3·78	− 3	729	" 19	16 02	685·67	56·67	+13
651	Mar. 6	16 15	641·67	12·67	10	730	" 19	17 50	685·75	56·75	+33
652	" 6	18 58	641·79	12·79	−34	735	" 24	14 03	690·59	61·59	+ 7
656	" 8	16 15	643·67	14·67	−34	737	" 24	15 25	690·64	61·64	+12
658	" 8	19 33	643·81	14·81	−42	738	" 26	16 20	692·68	63·68	+ 9
663	" 11	16 22	646·68	17·68	−37	740	" 27	16 10	693·67	64·67	+11
664	" 11	19 05	646·79	17·79	−25	742	May 2	13 22	698·56	69·56	+13*
668	" 20	15 43	655·65	26·65	+ 3	748	" 4	16 29	700·69	71·69	− 2
671	" 20	19 36	655·82	26·82	+12*	751	" 7	13 22	703·56	2·66	0
675	" 28	14 05	663·58	34·58	+13	754	" 9	13 30	705·56	4·66	− 6
689	Apr. 3	15 10	669·63	40·63	10	757	" 14	15 12	710·63	9·73	−29*
690	" 3	16 17	669·67	40·67	+25	761	" 18	16 05	714·67	13·77	−35
697	" 5	15 58	671·66	42·66	+30	763	" 20	15 07	716·63	15·73	−35
700	" 5	19 25	671·81	42·81	+19	773	" 23	13 36	719·57	18·67	−34
706	" 11	17 13	677·72	48·72	+17	777	" 24	13 25	720·56	19·66	− 5
707	" 11	18 07	677·75	48·75	+25	789	" 29	13 48	725·58	24·68	− 3
710	" 15	13 52	681·58	52·58	+18	795	" 31	14 06	727·59	26·69	+ 7
715	" 18	13 07	684·54	55·54	+23	811	June 10	13 35	737·57	36·66	+ 8
722	" 18	15 01	684·62	55·62	+ 2*	822	" 11	13 28	738·56	37·66	+ 7
723	" 18	17 57	684·75	55·75	+14	835	" 12	14 35	739·61	38·71	+20
725	" 19	13 19	685·55	56·55	+22	915	July 5	14 02	2,417,762·58	61·68	+11

* Mean of two or more measurements.

PREVIOUS OBSERVATIONS OF η VIRGINIS.

Date.	Julian Day.	Phase.	Velocity.	Residuals C—O.	Date.	Julian Day.	Phase.	Velocity.	Residuals C—O.
1903.					1903.				
Jan. 14	2,416,129·7	10·6	−28	2	Feb. 5	150·6	31·5	+ 3	+ 1
" 16	131·7	12·6	−31	− 5	May 17	251·7	60·7	+17	0
Feb. 4	149·7	30·6	+ 1	+ 2	" 24	2,416,258·7	67·7	+ 4	+ 6

In September the last of the plates was measured and approximate values of the elements were obtained from the oscillation curve. Some of the larger residuals are probably due to the low dispersion, as it does not permit of the resolution of the spectral lines of the two components unless they differ in velocity by about 70 km. per sec. In cases where there was not this difference in velocity the centre of intensity of the line would be shifted and an error would consequently be introduced in the setting. Then, too, there were certain gaps in the curve and, taking all things into consideration it was felt that more spectrograms would have to be secured before a rigid determination of the elements could be made.

The appearance of Naozo Ichinohe's article in the Astrophysical Journal for November, 1907, and the marked similarity of the oscillation curve there given to that obtained here decided us to review the data already secured. Some of the plates where the velocities for the different lines were not in good agreement with one another were remeasured, and a new determination of the elements was made. Preliminary values were obtained by the methods of Russell and Lehmann-Filhés as described in the report for last year and by a series of trials the values of the elements which

gave a curve most in accord with the observations was finally accepted. These values differed very little from the former ones; the period of $71{\cdot}9^d$ was found to suit the previous observations better than our value of $71{\cdot}7^d$, and it was accepted. A table of the previous observations known to the writer prior to the publication of the above article is given after the summary of the velocities.

The velocity curve (Fig. 11) computed from the following elements with the observed points is shown, as is also a graph of the orbit, Fig. 12.

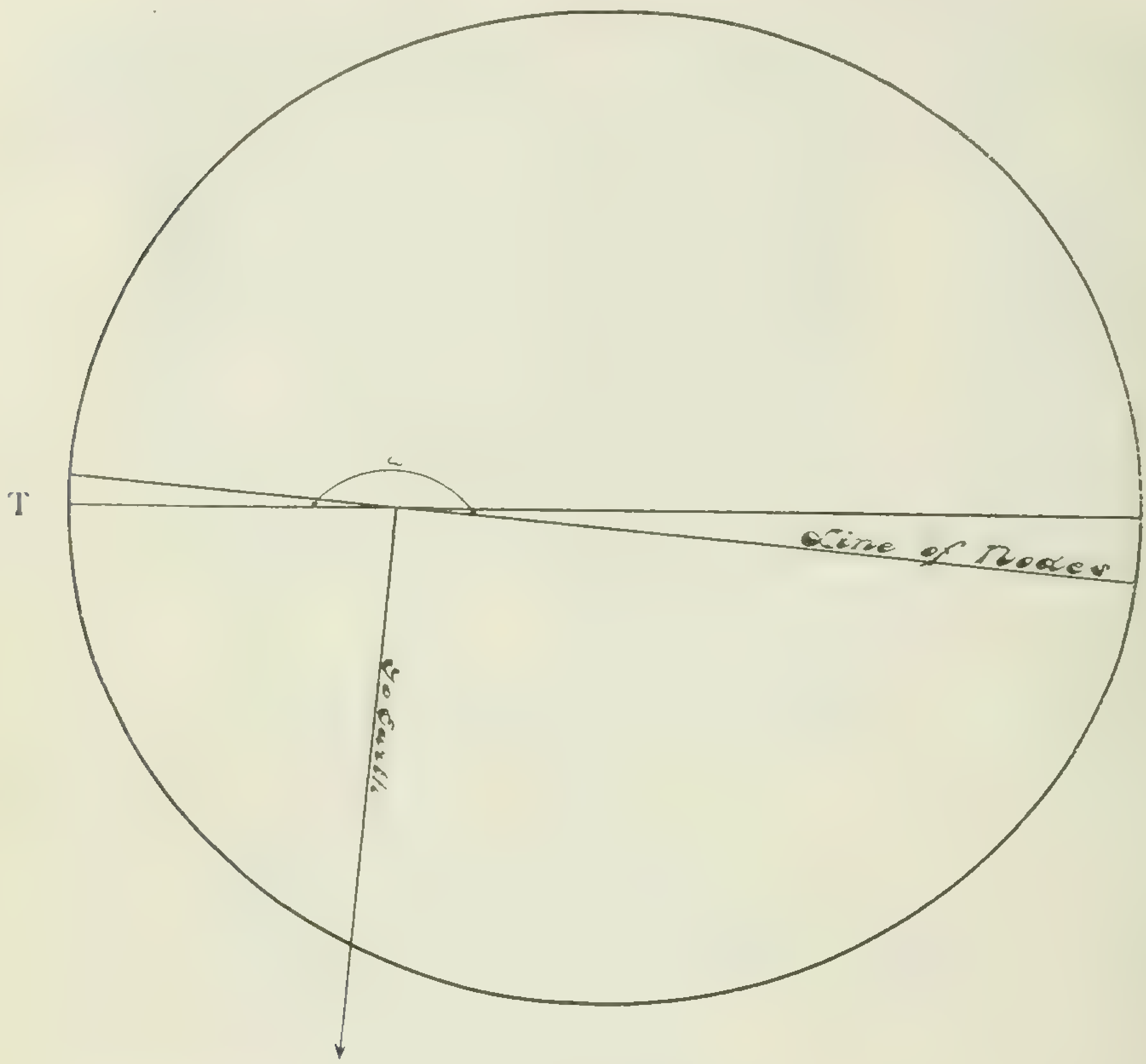


FIG. 12—Orbit of η Virginis.

It would be advisable, I think, to obtain a number of spectrograms of this star at selected epochs in its orbit with the new three-prism spectrograph whose dispersion is so much greater than those used before, and use these in conjunction with those already obtained to determine more accurate values of the elements, particularly the eccentricity.

These spectrograms would show the spectrum of the fainter component, and it might be possible to get sufficient measurements of its velocity to get an idea of the relative masses of the components.

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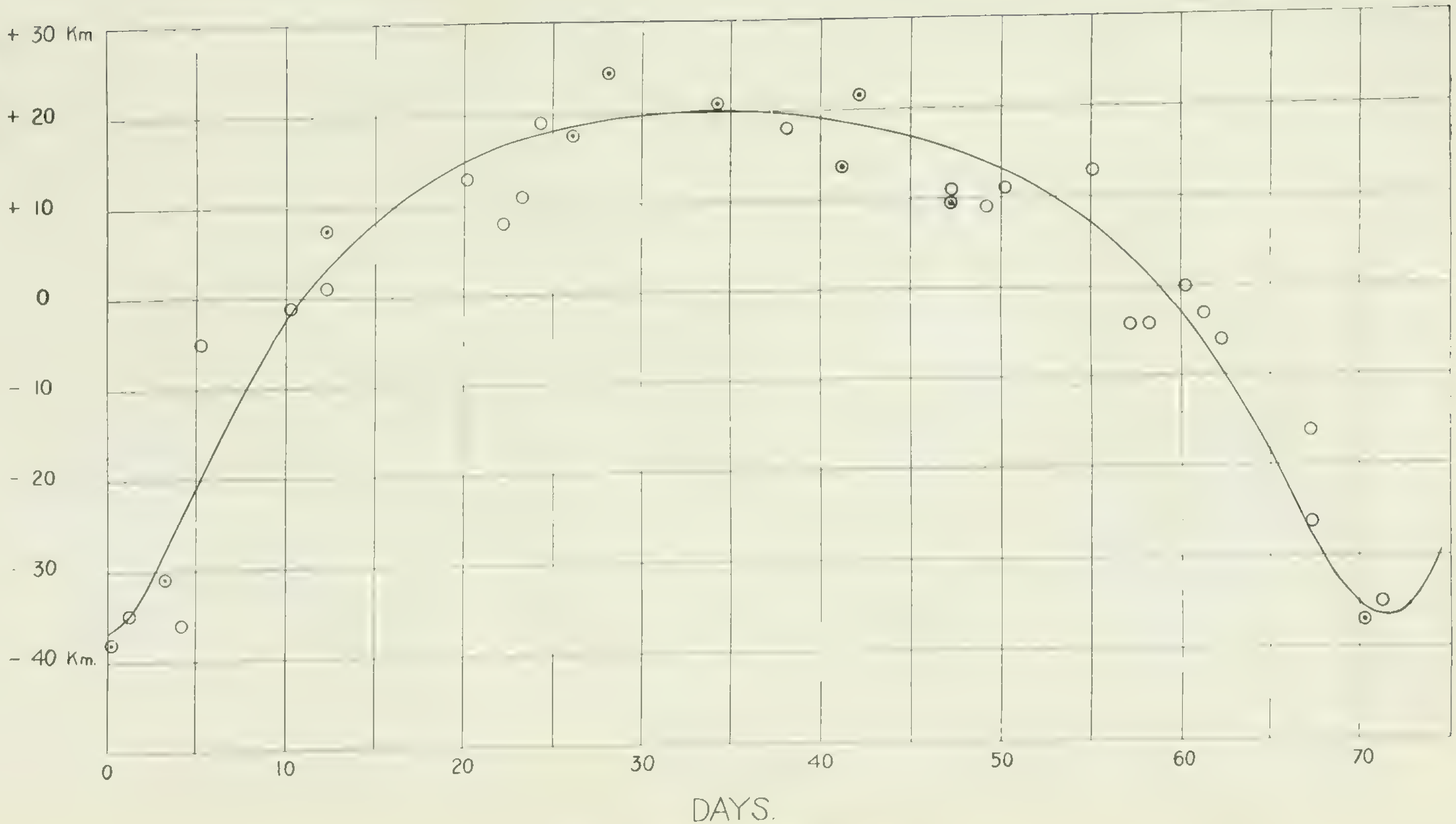

FIG. 11—Velocity Curve of η Virginis.

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The elements for the brighter component, which should be regarded as provisional only, are shown in the following table. For purposes of comparison the Yerkes results are attached.

ELEMENTS OF ORBIT OF η VIRGINIS.

Elements.	Ottawa.	Yerkes.	Elements.	Ottawa.	Yerkes.
P	71·9 d.	71·9 d.	Velocity of System	+2.2 km. per sec.	—0·4 km. per sec.
e	0·40	0·251	T	J.D. 2,417,643.50	J.D. 2,417,644.93
ω	185°	180°	$a \sin i$	25,750,000 km.	25,290,000 km.

APPENDIX B.

θ AQUILAE.

W. E. HARPER.

The star θ Aquilæ, $\alpha = 20^h\ 6{\cdot}2^m$, $\delta = -\ 1°\ 7'$, photographic magnitude 3·6, was one of the early-type stars selected for observation when the single-prism spectrograph was ready for use, about the middle of May of last year. Owing to lack of help the early spectrograms were not measured until the latter part of August. It was then noted that there was a rapid change at the time of maximum positive velocity and that this condition repeated itself about every 17 days. Attempts were, therefore, made to secure spectrograms of the star grouped around this critical phase, but in this we were only partially successful, as cloudy weather prevented us making all the observations we required at this particular epoch. Pending the securing of these the coming summer, it is well, I think, to give the provisional elements. Where two or more spectrograms were secured on one night the weighted mean of the velocities is used.

The spectrum of the star is of the type VII*a*, the four hydrogen lines H_β, H_γ, H_δ and H_ϵ along with the magnesium line λ 4481 and the K line λ 3933, being well adapted for measurement.

The plates were all reduced by the short method previously mentioned, the tables following giving all the required data in regard to micrometer settings and velocity per revolution. In the detailed statement of measures it would be advisable in future to have a column following 'Mean of Settings' entitled 'Corrections to Comparison Lines,' which would show the amounts that the settings on the comparison lines differ from the standard settings according to the tables. This would show at a glance how the corrected star settings were obtained from the corresponding lines in the mean of settings.

FE V COMPARISON LINES.

Wave Length.	Micrometer Readings. 20°	30	Wave Length.	Micrometer Readings. 20°	30°
4864·943	72 9636	73·0098	4341·162	45·2836	45·3736
4851·686	72·3993	72·4449	4325 941	44·2724	44·2593
4494 755	54 7266	54·7419	4099·921	27·3219	27·2466
4482·413	54·0153	54·0288	3969·411	15·2592	15·3986
4466·737	53 1007	53·1120	3930·450	11·6580	11·5072

STELLAR LINES IN θ AQUILAE.

Wave-Length.	20° Vel. per rev	20° Micr. Setting.	30° Vel. per rev.	30° Micr. Setting.	Wave-Length.	20° Vel. per rev.	20° Micr. Setting.	30° Vel. per rev.	30° Micr. Setting.
4861·527	1452·8	72·8187	1451·2	72·8648	4102 000	871·6	27·4965	867·9	27·4219
4481·400	1153 7	53·9566	1150 9	53 9698	3970·177	778·2	15·6035	774·3	15·4733
4340 634	1046 9	45 2487	1043·7	45·2387	3933·825	753·0	12 0004	749·0	11 8514

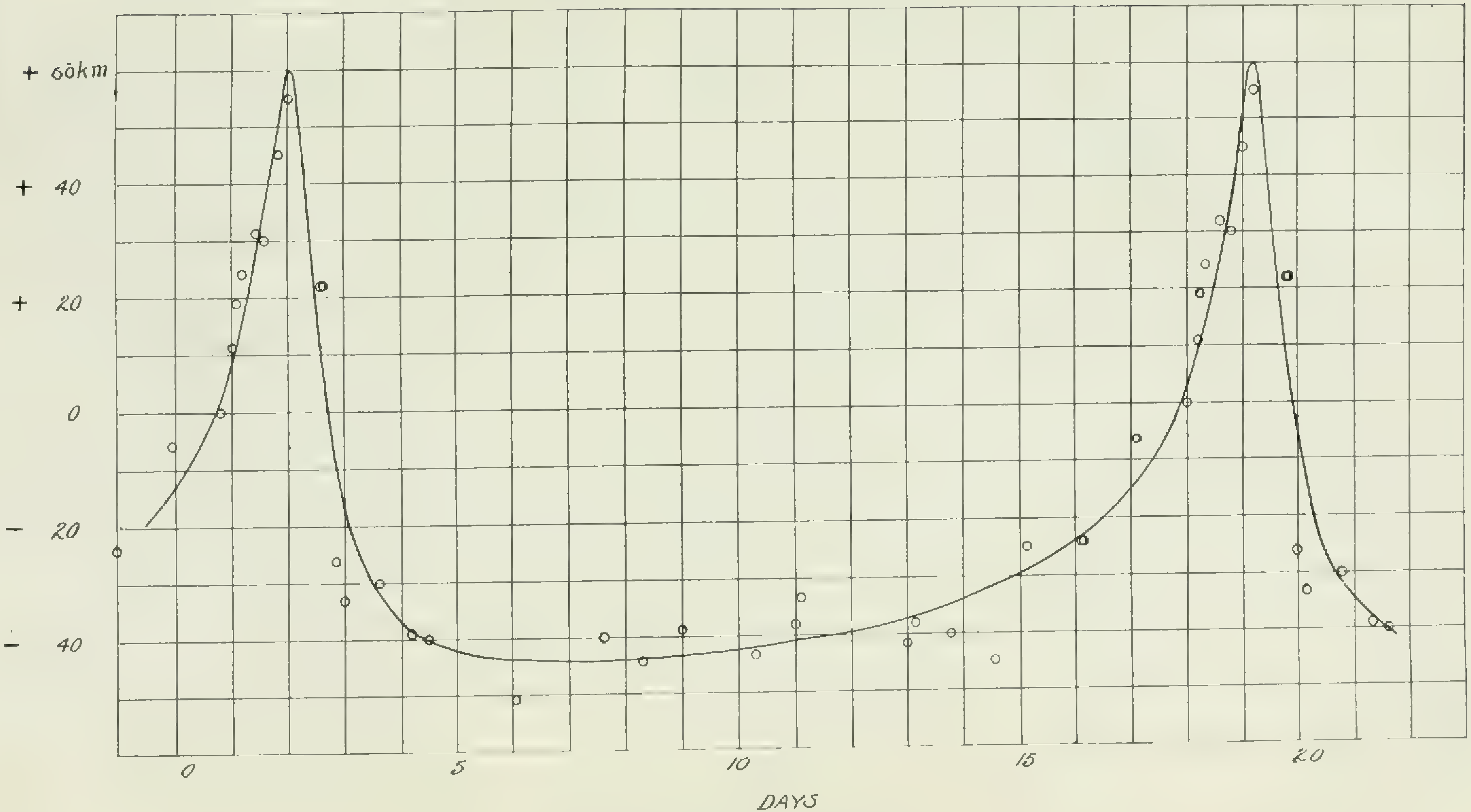


FIG. 13 Velocity Curve of θ Aquilæ.

In obtaining the period reference was made to Deslandres' observations* on this same star, but the residuals from the best curve that can be drawn through them are exceptionally large, and hence they were not taken into consideration. The period which suited our own observations best and which was finally decided upon was 17·17 days.

The elements which gave a curve most in accord with the observations were the following:—

P	=	17·17 days
Velocity of system	=	– 26·7 km. per sec.
e	=	– 0·725
ω	=	20° (measured from ascending node)
T	=	1907, Oct. 2·15 G.M.T.
	=	Julian Day 2,417,851·15
$a \sin i$	=	8,455,500 km.

The curve shown in the accompanying figure (Fig. 13) is computed from these elements, and with the exception of one or two cases the agreement is all that could be expected. A graph of the orbit is also shown (Fig. 14).

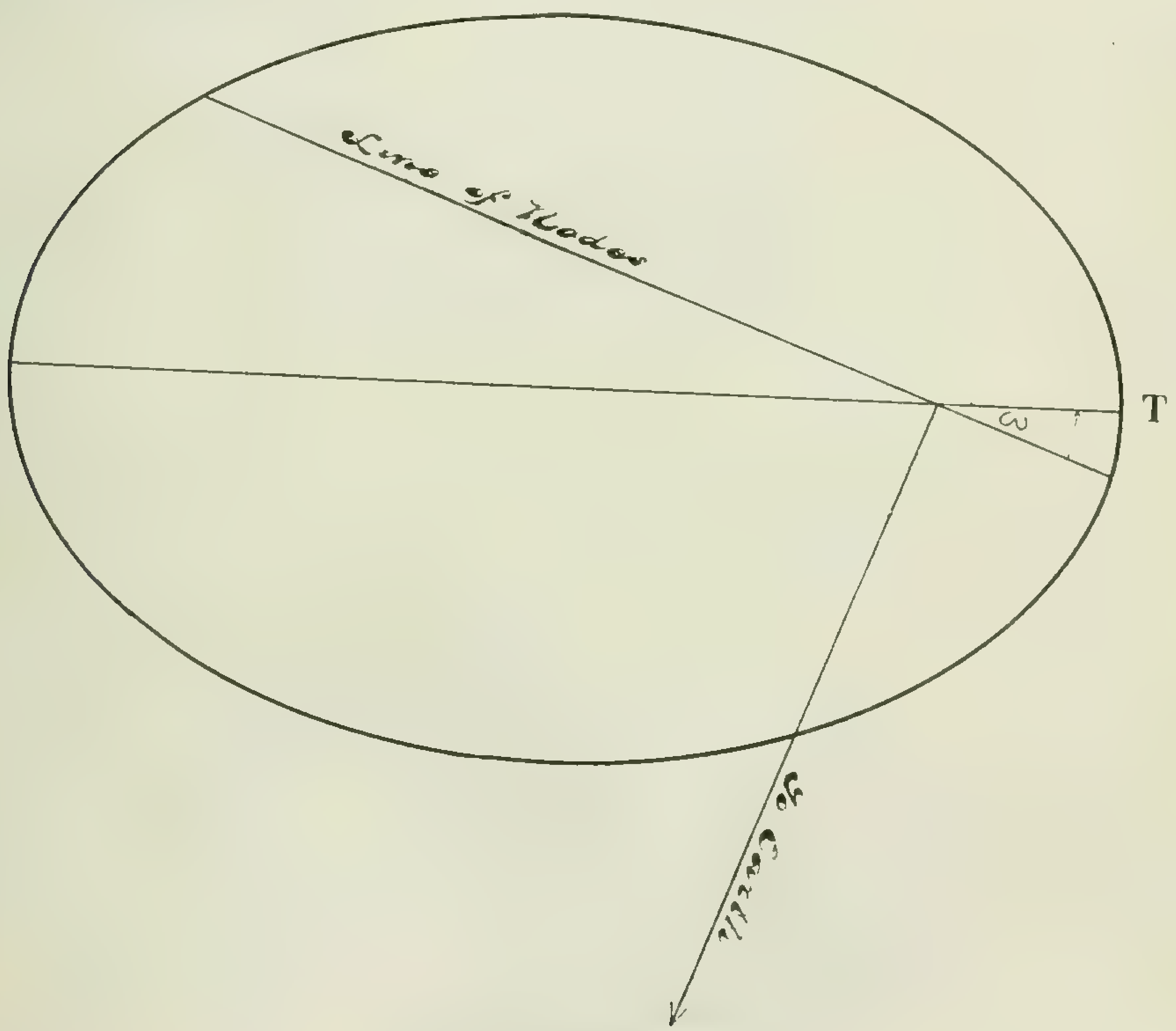


FIG. 14—Orbit of θ Aquilæ.

* Bull. Astr. 20, 129, 1903.

RECORD OF SPECTROGRAMS.

Star.	No. of Negative.	Camera.	Plate.	Date.		Middle of Exposure E. S. T.		Duration.	Hour Angle at end.		Comparison Spectrum. Exposure in Seconds.	Comparison Spectrum. Kind.	Temperature Centigrade. Room. Beginning.	Room. End.	Prism Box. Beginning.	Prism Box. End.	Slit Width.	Focal Position. Star Focus.	Collimator.	Camera.	Seeing.	Observer.	Remarks.
				1907.		h.	m.	m	h	m.													
θ Aquilae	803	IL	Seed 27	May	31	2	04	25	0	35 E	2 2 2 2	Fe V spark	12·6	12·6	18·7	18·75	·001	45·8	10·8	18·58	Good	P	
"	819	"	" 27	June	10	2	40	20		0	1½ 3 1	"	12·0	11·9	17·8	17·8	·0012	45·6	10·8	18·61	"	P	
"	832	"	" 27	"	11	1	53	23	0	47 E	3 3 3 3	"	13·5	12·5	18·9	18·8	·001	45·6	10·8	18·6	Fair	H	
"	841	"	" 27	"	12	3	05	20	0	25 W	2 4 2	"	14·5	14·2	18·9	18·8	·001	45·2	10·8	18·6	"	P	
"	854	"	" 27	"	14	2	36	20	0	20 W	2 5 2	"	19·4	19·3	23·0	23·0	·0012	45·2	10·8	18·7	Good	P	
"	865	"	" 27	"	20	1	40	20	0	25 E	3 6 3	"	19·5	19·5	25·4	25·4	·0013	44·5	10·8	18·68	Getting hazy	H	
"	873	"	" 27	"	21	2	20	20	0	15 W	6 12 6	"	22·3	22·2	29·0	29·0	·0013	46·0	10·8	18·63	Fair	P	
"	905	"	" 27	July	2	1	38	20	0	20 W	4 4 5	"	14·0	13·0	17·0	17·0	·0014	45·0	10·8	18·60	Good	H	
"	924	"	" 27	"	8	1	37	25	0	45 W	2 5 2	"	20·4	20·4	22·2	22·2	·0012	45·0	10·8	18·63	Poor to fair	P	
"	931	"	" 27	"	9	12	05	21	0	47 E	5 5 5	"	20·9		25·0		·0014	45·0	10·8	18·63	Good	T	
"	942	"	" 27	"	13	11	53	26	0	40 E	4 8 4	"	17·8	17·3	25·0	25·0	·0012	45·0	10·8	18·72	Fair to poor.	T	
"	946	"	" 27	"	16	12	07	26	0	17 E	5 7 5	"	24·0	23·4	26·6	26·6	·0014	45·0	10·8	18·7	Hazy.	H	
"	959	"	" 27	"	20	1	19	22	1	13 W	4 8 4	"	17·6	17·5	21·4	21·4	·0012	45·0	10·8	18·7	Good	P	
"	969	"	" 27	"	27	1	15	30	1	42 W	4 5 5 4	"	19·6	19·4	22·3	22·3	·0012	45·0	10·8	18·74	Fair	P	
"	1001	IHL.	" 27	Aug.	10	10	50	50	0	20 W	11 10 10 11	"	23·1	22·4	28·8	28·7	·002	45·0	10·8	2·9	"	P	
"	1012	IL	" 27	"	13	11	37	35	1	00 W	8 8 8	"	17·0	16·8	24·2	24·2	·0014	45·0	10·8	18·75	Light clouds	T	
"	1013	"	" 27	"	15	8	45	80	1	10 E	8 10 6	"	22·3	19·5	26·3	26·3	·0014	45·0	10·8	18·75	Very poor	H	Seen thro. thick haze
"	1023	"	" 27	"	23	11	10	60	1	15 W	8 10 8	"	20·0	18·6	27·0	27·0	·0012	73·0	10·8	18·49	Hazy.	T	
"	1027	"	" 27	"	27	11	04	52	1	40 W	11 11	"	15·0	14·0	20·0	19·7	·0012	73·0	10·8	18·2	Fair	T	
"	1028	"	" 27	"	27	10	07	55	0	45 W	7 10 8	"	16·5	15·0	20·1	20·0	·0012	73·0	10·8	18·2	"	T	
"	1033	"	" 27	Sept.	6	9	41	72	1	15 W	8 8 8	"	18·3	18·2	21·0	21·0	·0012	73·0	10·8	18·5	Cloudy.	T	
"	1038	"	" 27	"	12	10	15	41	1	55 W	8 8 8	"	16·8	15·7	20·9	20·9	·0012	73·0	10·8	18·6	Good	T	
"	1043	"	" 27	"	14	11	10	50	2	50 W	6 5 5	"	20·7	20·1	21·1	21·0	·0011	73·0	10·8	18·6	Poor	P	Thick haze.
"	1050	"	" 27	"	18	9	15	37	1	40 W	8 8 8	"	12·5	11·7	17·1	17·0	·0014	44·5	10·8	18·41	Fair	T	
"	1072	"	" 27	"	30	8	02	20	0	40 W	6 5 5 6	"	9·4	8·8	13·4	13·4	·0011	73·0	10·8	18·18	Good	P	
"	1073	"	" 27	"	30	8	25	20	1	00 W	5 10 5	"	8·8	8·6	13·3	13·2	·0011	73·0	10·8	18·18	"	P	
"	1074	"	" 27	"	30	9	08	24	1	45 W	5 6 6 5	"	8·6	8·1	13·2	13·2	·0011	73·0	10·8	18·18	"	P	
"	1080	"	" 27	Oct.	1	7	03	26	0	15 E	5 6 6 5	"	12·5	11·5	14·5	14·3	·0012	73·0	10·8	18·2	Fair	H	
"	1081	"	" 27	"	1	7	32	31	0	15 W	6 10 6	"	11·5	12·0	14·3	14·3	·0012	73·0	10·8	18·2	Steadier.	H	
"	1082	"	" 27	"	1	8	09	41	0	57 W	6 10 6	"	12·0	10·5	14·3	14·2	·0012	73·0	10·8	18·2		H	
"	1085	"	" 27	"	1	9	43	35	2	28 W	6 12 6	"	10·2	10·0	14·1	14·1	·0014	73·0	10·8	18·2	Hazy	H	
"	1086	"	" 27	"	1	10	24	42	3	13 W	6 12 6	"	10·0	9·0	14·1	14·1	·0014	73·0	10·8	18·2	"	H	
"	1089	"	" 27	"	2	7	41	26	0	20 W	11 11	"	14·0	13·2	15·1	15·1	·0012	72·0	10·8	18·28	"	T	
"	1091	"	" 27	"	2	8	40	25	1	19 W	11 11	"	13·2	12·0	15·0	15·0	·0012	72·0	10·8	18·28	Fairly good	T	
"	1092	"	" 27	"	2	9	08	26	1	50 W	6 10 6	"	12·0	11·2	15·0	15·0	·0012	72·0	10·8	18·28	Fair	T	

"	..	1093	" .	"	27	"	2	9	36	27	2	19 W		6	10	6	"		11 2	10 0	15 0	15 0	0012	72 0	10 8	18 28	..	T	
"	.	1094	" .	"	27	"	2	9	59	12	2	41 W		6	10	6	"		11 0	11 0	15 0	15 0	0012	72 0	10 8	18 28	.	T	Stopped: rain.
"	.	1100	111L	"	27	"	18	7	15	60	1	19 W	8	8	8	10	"		6 5	4 5	10 8	10 7	0018	72 0	10 8	25 7	Fair (?). ..	H	New Camera Tube.
"	..	1101	" .	"	27		18	8	46	12	3	16 W's	8	8	4	10	"	..	4 5	3 0	10 7	10 4	0018	72 0	10 8	25 7	Poor	H	Clouds.
"	..	1106	"	"	27	"	25	7	52	58	2	30 W	12	12	12	12	"	..	4 5	..	8 0	8 0	0015	72 5	10 8	25 67	Cloudy. .	P	
"	..	1128	IL	"	27	Nov	4	5	28	20	0	20 W	4	4	4	4	"	..	3 7	4 1	8 1	8 1	0012	72·5	10 8	18 27	Good ...	P	
"	..	1129	" .	"	27	"	4	5	51	18	0	40 W	4	4	4	4	"	..	4 1	3 5	8 1	8 1	0012	73 4	10 8	18 27	" ..	P	
"	..	1146	" .	"	27	"	16	7	00	30	2	40 W		7-	10	7		..	1 3	1·3	1 7	1 7	0013	73 5	10 8	18 18	Fair .. .	P	
"	..	1149	" ..	"	27	"	18	5	45	10	1	30 W			10	8	,		4 6	4 5	5 1	5 1	0013	74 0	10·8	18 18	Hazy. . .	P	Stopped.
"	..	1150	" .	"	27	"	18	7	37	35	3	30 W		8	10-	8	"	..	4 3	4·9	5 0	5 0	0013	74·0	10 8	18·18	" .	P	
"	..	1154	"	"	27	"	19	5	41	17	1	30 W	5	6	6	5	"	..	3·0	2·3	7 0	7 0	0013	74 0	10 8	18·18	Fair to good	P	
"	..	1155	" ..	"	27	"	19	6	00	16	1	50 W		5	10	5	"	..	2·3	2 3	7 0	7 0	0013	74 0	10 8	18 18	"	P	
"	..	1157	" ..	"	27	"	23	7	42	25	3	50 W		4	7-	4	"	.	2 6	2 5	7 0	6 9	0013	74 0	10 8	18 18	Fair. . ..	P	

θ AQUILAE. 803

1907. May 31. Observed by J. S. PLASKETT.
G. M. T. 19^h 04^m Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.
1	72·9587	...	...	...	2	45·2775	...	...	...
2	72·7821	72·7877	·0310	−45·04	1	45·1980	45·2062	·0425	−44·50
½	72·3927	...	...	...	1½	44·2609	...	...	...
1	54·7196	...	...	...	1½	30·9144	...	...	...
2	53·9103	53·9155	·0411	−47·42	¼	27·4088	27·4336	·0629	−54·82
1	53·6928	...	...	...	2	27·2933	...	...	...

Weighted mean .... — 46·31
V_a .... 22·75
V_d .... + ·09
Curvature .... — ·28

Radial velocity .... — 23·7

θ AQUILAE. 819

1907. June 10. Observed by J. S. PLASKETT.
G. M. T. 19^h 40^m Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.
2½	72·9497	...	...	...	2	45·3075	...	...	...
1	72·7530	72·7662	·0525	−76·27	2	45·2115	45·1915	·0562	−58·84
1¾	72·3880	...	...	...	2	44·2883	...	...	...
2	54·7395	...	...	...	1½	30·9602	...	...	...
2	53·9247	53·9099	·0467	−53·88	¼	27·4324	27·4620	·0345	−30·07
2	53·1164	...	...	...	1½	27·3512	...	...	...

Weighted mean .... — 58·71
V_a .... + 20·06
V_d .... 0·0
Curvature .... — ·28

Radial velocity .... — 38·9

θ AQUILAE 841.

1907. June 12. Observed by J. S. PLASKETT.
G. M. T. 20^h 05^m Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.
1½	72·9574	...	...	...	1¾	45·2946	...	...	...
2	72·7739	72·7779	·0408	−59·27	2	45·2019	45·1925	·0562	−58·83
1½	72·3986	...	...	...	1¼	44·2799	...	...	...
1	54·7404	...	...	...	1½	30·9462	...	...	...
3	53·9214	53·9122	·0444	−51·22	¼	27·4002	27·3882	·1083	−94·39
2	53·1075	...	...	...	1½	27·3344	...	...	...

Weighted mean .... −57·02
V_a .... +19·02
V_d .... 0·0
Curvature .... — ·28

Radial velocity .... −38·3

θ AQUILAE 854.

1907. June 14
G. M. T. 19h 36m

Observed by J. S. Plaskett.
Measured by J. N. Tribble.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.
2	72·9749	....	....	....	2	45·2778	....	....	....
2	72·7903	72·7807	·0380	−55·20	2	45·1867	45·1835	·0652	−68·25
2	72·4093	....	....	....	1½	44·2598	....	....	....
2	54·7313	....	....	....	1	30·9014	....	....	....
2	53·9121	53·9109	·0457	−52·72	½	27·3800	27·3442	·1523	−132·74
1½	53·0980	....	....	....	2	27·2826	....	....	....

Weighted mean .... − 59·94
V_a .... + 18·33
V_d .... 0·0
Curvature .... − ·28

Radial velocity .... − 41·9

θ AQUILAE 865.

1907. June 20.
G. M. T. 18h 40m

Observed by W. E. Harper.
Measured by J. N. Tribble.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.
2	54·7079	......	....	......	2	53·0799	..	....	......
2	53·9698	53·9874	·0308	+35·53					

Velocity............... +35·53
V_a .... +16·12
V_d .... + ·04
Curvature .... − ·28

Radial velocity. ..... +51·4

θ AQUILAE 865*

1907. June 20.
G. M. T. 18h 40m

Observed by W. E. Harper.
Measured by J. N. Tribble.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.
2	54·7570	....	....	....	2	53·1294	....	....	....
2	54·0117	53·9941	0243	+27·97					

Velocity. .... +27·97
V_a .... +16·12
V_d .... + ·04
Curvature............... − ·28

Radial velocity ...... +43·8

* Check measurement.

θ AQUILAE 865*

1907. June 20. Observed by } W. E. Harper.
G. M. T. 18h 40m Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.
2	27·0238				1	27·0055	27·0110	0221	+25·50

Velocity	+25·50
V_a	+16·12
V_d	·04
Curvature	·28
Radial velocity	41·4

* Second check measurement: Accepted result = +44·7.

θ AQUILAE 873.

1907. June 21. Observed by J. S. Plaskett.
G. M. T. 19h 20m Measured by J. N. Tribble.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.
2	73·0071				1½	45·2815			
2	72·8333	72·8349	0299	—43·39	2	45·2132	45·2060	0327	34·12
2	72·4446				1	44·2586			
1½	54·7358				1	30·8942			
1½	53·9063	53·9107	0591	—68·01	½	27·3968	27·3638	0581	—50·42
1	53·1084				1½	27·2815			

Weighted mean	—47·04
V_a	15·73
V_d	0·0
Curvature	— ·28
Radial velocity	—31·6

θ AQUILAE 873*

1907. June 21. Observed by J. S. Plaskett.
G. M. T. 19h 20m Measured by J. N. Tribble.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	73·0948				1½	54·8292			
2	72·9181	72·8328	0320	—46·43	1½	54·0185	53·9320	0378	—43·51
2	72·5309				1	53·1977			
1	57·9187				2	45·3701			
¼	57·8835	57·7848	0420	—50·56	2	45·3099	45·2134	·0253	—26·41

Weighted mean	—38·16
V_a	+15·73
V_d	0·0
Curvature	— ·28
Radial velocity	—22·7

* Check measurement: Accepted result —26·0

η AQUILAE 905

1907. July 2.
G. M. T. 18h 12m

Observed by W. E. HARPER.
Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9584				1½	53·1104			
1½	72·7668	72·7706	0481	69·88	2	45·2928			
2	72·3976				1	45·2075	45·1983	0504	−52·76
2	57·8160				1	44·2863			
¼	57·7946	57·7826	0221	26·66	1	30·9505			
2	54·7359				1	27·4637	27·4493	0472	−41·14
2	53·9277	53·9181	0385	14·42	1½	27·3353			

Weighted mean	−51·17
V_a	11·04
V_d	— ·04
Curvature	·28
Radial velocity	−40·4

η AQUILAE 924.

1907. July 8.
G. M. T. 18h 37m

Observed by J. S. PLASKETT.
Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	72·9555				1½	53·0880			
1½	72·8062	72·8126	0061	8·86	2	45·2631			
2	72·3933				2	45·2533	45·2733	0246	+25·75
2	57·7936				1	44·2544			
1½	57·8051	57·8095	0048	+ 5·80	1½	30·8929			
1½	54·7202				¼	27·4617	27·4993	0028	+ 2·44
1½	53·9617	53·9685	0119	+13·72	3	27·2836			

Weighted mean	+11·21	
V_a	+ 8·40	
V_d		— ·09
Curvature		— ·28
Radial velocity	+19·2	

θ AQUILAE 924*

1907. July 8.
G. M. T. 18h 37m

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9278	...	...	...	2½	45·2272	45·2774	·0287	-30·05
2	72·7749	72·8100	·0087	—12·64	½	29·6211	30·8930	·0226	-20·11
2	72·3660	...	...	...	2	21·5985	...	...	...
2	54·6897	...	...	...	½	27·4500	27·5161	·0196	+17·09
1½	53·9352	53·9742	·0176	20·31	2	27·2558	...	...	...
2	53·0594	...	...	...	1	11·9297	12·0382	·0378	+28·35
2	45·2334	...	...	...	2	11·5495	...	...	...

Weighted mean.	– 15·90	
V_a	+ 8·40	
V_d		— ·09
Curvature................		— ·28
Radial velocity........	+23·9	

*Check measurement: Accepted result +22·5.

θ AQUILAE 931.

1907. July 9.
G. M. T. 17h 05m

Observed by } J. N. Tribble.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	73·4571	...	...	...	2	53·1141	...	...	...
2	73·0042	...	...	...	2	45·2822	...	...	...
½	72·8455	·8523	·0125	—18·14	2	45·2091	·2011	·0376	39·24
2	72·4370	...	...	...	1	44·2666	...	...	...
2	57·8287	...	...	...	2	27·2910	...	...	...
¼	57·7855	·7762	·0506	60·91	¼	27·4191	·3759	·0560	48·21
1	54·7475	...	...	...	2	29·6336	...	...	...
½	54·0332	...	...	...	½	29·6000	·5653	·0346	30·69
2	53·9400	·9356	·0342	39·56	½	29·8200	·7857	·0452	—39·09

Weighted mean......		—37·80
V_a	+ 8·80	
V_d	+ ·04	
Curvature...............		— ·28
Radial velocity.		—29·2

θ AQUILAE 942.

1907. July 13.
G. M. T. 16ʰ 53ᵐ

Observed by } J. N. TRIBBLE.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	72·9882	....	....	....	1½	45·3032	....	....	....
1	72·8082	72·8298	·0350	50·79	2	45·2277	45·1989	·0398	42·57
1	72·4244	....	....	....	1	44·2829	....	....	....
1½	54·7572	....	....	....	1	30·9164	....	....	....
1½	53·9366	53·9214	·0484	55·70	1	27·4847	27·3943	·0276	—23·96
1½	53·1282	....	....	....	1½	27·3376	....	....	....

Weighted mean........ —47·72
V_a .... + 6·52
V_d .... + ·04
Curvature .... — ·28

Radial velocity........ —41·4

θ AQUILAE 942*

1907. July 13.
G. M. T. 16ʰ 53ᵐ

Observed by } J. N. TRIBBLE.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	73·4241	....	....	....	1½	53·1067	....	....	....
1½	72·9724	....	....	....	1½	45·2826	....	....	....
1	72·7909	72·8293	·0355	—51·51	2	45·2066	45·1978	·0409	42·68
1	72·4062	....	....	....	1	44·2613	....	....	....
1½	54·7351	....	....	....	1	27·4545	27·3805	·0414	—35·93
1½	53·9333	53·9393	·0305	35·10	1½	27·3206	....	....	....

Weighted mean .... 41·85
V_a .... + 6·52
V_d .... + ·04
Curvature.......... — ·28

Radial velocity........ — 35·6

* Check measurement: Accepted result —38.5

θ AQUILAE 946.

1907. July 16.
G. M. T. $17^h\ 07^m$

Observed by W. E. HARPER.
Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	73·4087	....			1½	53 8869	53 9285	0413	47·53
1½	72·9526		...	.. ..	2	53·0710		....	....
1	72·7737	72·8305	0343	49 77	2	45·2437	..		... ...
1½	72·3863	. .	.		½	45 1664	45·1964	0423	– 44·15
2	54·7003	..	.....	. ...	1	44·2312	..	...	.. ...

Weighted mean 47 71
V_a .... + 4·88
V_d .... 0·0
Curvature............ — ·28

Radial velocity. ... ... – 43 1

θ AQUILAE 959.

1907. July 20.
G. M.. T $18^h\ 19^m$

Observed by J. S. PLASKETT.
Measured by J. N. TRIBBLE.

Wt.	Mean of Setting	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9119	... ...	. .	... ...	2	45 2369	. . .	... .	. . . .
1½	72·7329	·7833	·0354	51 43	1½	45 1626	2094	·0393	41·14
2	72·3508	.....	....	. ....	2	44·2224	. . .	. ...	.....
2	54 6814	... ...	. .	....	2	27 2722	... .	....	.. ..
1½	53·9721	. ...	....	....	1/10	27 3751	·4247	0718	62 64
2	53·8684	·9132	·0434	50 07	2	29·6149	... .	. . ..	.. ..
1½	53 0549	... .	....	....	½	29·5662	·5502	0487	– 43·20

Weighted mean.............. – 47·80
V_a .... + 3·26
V_d .... – ·12
Curvature..... .. – ·28

Radial velocity........... ... – 45·0

θ AQUILAE 969.

1907. July 27.
G. M. T. 18^h 15^m

Observed by J. S. PLASKETT.
Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	73·4342	....		....	2	53·1138	....	...	......
1½	72·9853			....	1½	45·2891		....	.....
1½	72·8185	72·7985	·0202	−29·54	1	45·2132	45·1980	·0507	53·07
1	72·4147	....	....	....	1	44·2780		...	....
2	54·7455			....	2	27·3001		....	.....
2	53·9410	53·9250	·0316	36·57	1	27·4208	27·4426	·0539	46·98

Weighted mean.........		−39·54
V_a.....	−	·38
V_d....................	−	·16
Curvature................	−	·28
Radial velocity..........		−40·4

θ AQUILAE 1001.

1907. August 10.
G. M. T. 15^h 50^m

Observed by J. S. PLASKETT.
Measured by J. N. TRIBBLE.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Norma W. L.	Displacement.	Velocity.
91·9339	....	...	....	....	48·8913	.....	...	....	....
91·6041	4861·849	·527	·322	+19·86	41·5033	....	....	....	....
90·5151	.....	....	....	....	41·4103	4481·847	·400	·447	29·90
52·0883	....	.....	....	....	15·9546	....	......	....	....
52·1325	4549·934	·642	·292	19·23	15·9417	4341·097	·634	·463	+31·97
49·7977	4534·650	·139	·511	33·79					

Mean.....	+26·35	
V_a		− 6·99
V_d....................		− ·09
Curvature..		− ·50
Radial velocity...	+18·7	

θ AQUILAE 1012.

1907. August 13.
G. M. T. $16^h\ 37^m$

Observed by / Measured by J. N. Tribble.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	73·3276	...	...	...	2	53·9312	53 9328	·0238	27·46
2	72·8801	...	...	...	2	53·0999	...	...	...
½	72·7022	72·7858	·0329	−47·80	2	45 3077	...	...	...
1½	72·3198	...	...	...	1½	45·2467	45·2227	·0260	27·22
1½	54 7199	...	...	...	1½	27·3844	...	...	...
1	54 0126	...	...	...	⅓	27·5058	27·4433	·0532	−46·36

Weighted mean	−30·67
V_a	− 8·14
V_d	·10
Curvature	− ·28
Radial velocity	39 2

θ AQUILAE 1013.

1907. Aug. 15.
G. M. T. $13^h\ 45^m$

Observed by W. E. Harper.
Measured by J. N. Tribble.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	73·4972	...	...	...	2	53·1509	...	...	...
¼	72·8749	8385	·0263	−38 17	2	45·3155	...	...	...
2	72·4827	...	...	...	½	45·2329	·1910	0477	49·79
1	57·8689	...	...	...	1¼	27·3231	...	...	...
1	57·8453	·7964	0304	36 60	¼	27·4570	3805	·0414	35 93
2	54·7839	...	...	...	2	29·6705	...	...	...
2	54 0753	...	...	...	¼	29 6300	·5584	0415	36 81
2	53·9743	9303	·0395	45·46	¼	29·8453	·7737	·0572	−50·74

Weighted mean	−42 88
V_a	− 9·09
V_d	− ·02
Curvature	− ·28
Radial velocity	−52 2

θ AQUILAE 1013.*

1907. Aug. 15. Observed by W. E. HARPER.
G. M. T. 13h 45m Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9861				2	53·0973			
1½	72·8133	72·8358	·0290	—42·08	2	45·2600			
2	72·4265				2	45·1777	45·1912	·0475	49·59
2	54·7309				1½	27·4140	27·3969	·0250	—21·70
2	53·9212	53·9340	·0358	40·92	2	27·2640			

Weighted mean .... —39·50
V_a .... — 9·09
V_d .... + ·02
Curvature .... — ·28

Radial velocity .... —48·8

*Check measurement.

θ AQUILAE 1013.*

1907. Aug. 15. Observed by / Measured by W. E. HARPER.
G. M. T. 13h 45m

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	57·8190				2	53·1012			
1½	57·7872	57·7882	·0386	−46·47	2	45·2678			
2	54·7343				1	45·1805	45·1863	·0524	—54·70
3	53·9288	53·9383	·0316	36·37					

Weighted mean .... —42·40
V_a .... — 9·09
V_d .... + ·02
Curvature .... — ·28

Radial velocity .... —51·7

*2nd check measurement: accepted result—51·0.

θ AQUILAE 1023.

1907. Aug. 23. Observed by / Measured by J. N. TRIBBLE.
G. M. T. 16h 10m

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	73·5028				1½	54·0172			
1½	73·0477				2	53·9494	53·9606	·0092	—10·58
½	72·9054	72·8689	·0041	+ 5·95	2	45·2485			
2	54·7393				½	45 1963	45·2214	·0173	—18·05

Weighted mean .... — 9·07
V_a .... —12·54
V_d .... — ·11
Curvature .... — ·28

Radial velocity .... —22·0

θ AQUILAE 1027.

1907. Aug. 27.
G. M. T. 16h 04m

Observed by } J. N. TRIBBLE.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revolutions.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	73·5058	....	....	....	2	54·0181	53·9796	0230	25·54
2	73·0592	....	....	....	2	45·2866	....	....	....
¼	72·9186	72·8260	·0083	+12·06	¼	45·2893	45·2863	0376	39·36
2	54·0540	....	....	....					

Weighted mean....... + 25·57
V_a .... —14·64
V_d .... — ·14
Curvature .... — ·28

Radial velocity....... +10·5

θ AQUILAE 1027*

1907. Aug. 27.
G. M. T. 16h 04m

Observed by J. N. TRIBBLE.
Measured by W. E. HARPER.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	73·0842	....	....	....	2	45·3156	....	....	....
1	72·9458	72·8726	·0078	+11·32	1	45·3100	45·2680	·0293	30·59
2	72·5146	....	....	....	2	11·9111	11·8870	·0356	+26·70
2	54·0800	....	....	....	2	11·5313	....	....	....
3	54·0478	53·9966	·0268	30·85					

Weighted mean....... +26·84
V_a .... —14·64
V_d .... — ·14
Curvature .... — ·28

Radial velocity....... +11·8

* Check measurement: Accepted result +11·0

θ AQUILAE 1028.

1907. Aug. 27.
G. M. T. 15h 07m

Observed by } J. N. TRIBBLE.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	54·1520	....	....	....	2	45·3914	....	....	....
2	54·1201	53·9834	·0268	+30·92	½	45·3592	45·2514	·0027	+ 2·82

Weighted mean..... + 25·3........
V_a ....— 14·64
V_d ....— ·14
Curvature ....— ·28

Radial velocity......+ 10·2

θ AQUILAE 1033.

1907. Sept. 6.
G. M. T. $14^h\ 41^m$

Observed by } J. N. TRIBBLE.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	73·5147	....	....	....	2	53·9767	53·9465	0101	11·65
1½	73·0689	....	....	....	2	45·2635	....	....	....
½	72·8971	72·7915	·0272	—39·51	1½	45·2185	45·2386	·0101	10·57
1½	54·7499	....	....	....	1	27·3399	27·4699	·0266	—23·18
2	54·0455	....	....	....	2	27·1967	....	....	....

Weighted mean.............. —16·42
V_a .... —16·70
V_d .... — ·14
Curvature. .... — ·28

Radial velocity............. — 33·5

θ AQUILAE 1033*.

1907. Sept. 6.
G. M. T. $14^h\ 41^m$

Observed by J. N. TRIBBLE.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity
2	72·9980	....	....	....	2	45·1915	....	....	....
1½	72·8333	72·8458	·0190	—27·57	1½	27·2830	27·3899	·0320	27·78
2	72·4309	....	....	....	2	27·1395	....	....	....
2	54·6784	....	....	....	1½	11·6990	11·8364	·0150	—11·24
1½	53·9075	53·9403	·0295	33·72	2	11·3692	....	....	....
2	53·0469	....	....	....					

Weighted mean .... —25·08
V_a .... —16·70
V_d .... — ·14
Curvature.. .... — ·28

Radial Velocity........... —42·2

* Check measurement ; Accepted result —37·0.

θ AQUILAE 1038

1907. Sept. 12.
G. M. T. $15^h\ 15^m$

Observed by } J. N. TRIBBLE.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	54·0454	....	....	....	1	45·2527	45·2704	0217	22·71
½	53·9962	53·9661	·0095	+10·96	½	27·3854	27·5003	·0038	+ 5·31
2	45·2659	....	....	....	1½	27·2070	....	....	....

Weighted mean........ + 6.58
V_a .... —20·23
V_d .... — ·14
Curvature .... — ·28

Radial velocity .... —14·1

θ AQUILAE 1038.*

1907. Sept. 12.
G. M. T. $15^h\ 15^m$

Observed by } J. N. TRIBBLE.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1⅓	73·5342	.	.. .	.. . .	2	45·2734	....	.	..
1½	73·0814	... .	. . .	.	1	45·2544	45·2646	·0159	+16·64
1	72·9261	72·8091	·0096	−13·95	2	27·2135	. ....	.	.
1⅓	54·0557	....	.. .	. .	½	27·3818	27·4898	·0067	−5·84
½	54·0120	53·9720	·0154	+17·76					

Weighted mean...... + 1·90
V_a .... −20·23
V_d .... − ·14
Curvature .... − ·28

Radial velocity........ −18·7

*Check measurement: Accepted result — 16·4.

θ AQUILAE 1043.

1907. Sept. 14.
G. M. T. $16^h\ 10^m$

Observed by J. S. PLASKETT.
Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	54·0505	. ....	.....	....	2	45·2726	..... .	....	....
1½	54·0762	54·0412	·0846	+98·06	1½	45·2981	45·3091	·0604	−63·23

Weighted mean...... +80·64
V_a .... −20·91
V_d .... − ·21
Curvature............... − ·28

Radial velocity... ... +59·2

θ AQUILAE 1043.*

1907. Sept. 14.
G. M. T. $16^h\ 10^m$

Observed by J. S. PLASKETT.
Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	54·0608	... .	. ....	. .	2	45·2820	....	....	.. ...
1	54·0745	54·0290	·0724	+83·52	1	45·2992	45·3008	·0521	+54·54

Weighted mean..... +70·00
V_a .... −20·91
V_d ... . − ·21
Curvature.. . ... − ·28

Radial velocity. +48·6

* Check measurement.

θ AQUILAE 1043. ‡

1907. Sept. 14.
G. M. T. 16h 10m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	73·0962	......	......	......	1½	45·3255	45·3144	·0757	79·03
½	72·9696	72·8923	·0275	+40·00	2	45·2847	......	......	......
2	72·5349	......	......	......	1	29·6640	29·6703	·0862	76·46
2	54·7793	......	......	......	2	29·5777	......	......	......
2	54·0680	54·0332	0634	72·97	½	27·4749	27·4911	·0692	60·06
2	54·0653	......	......	......	2	27·2302	......	......	......
2	53·1417	......	......	......	½	11·8837	11·9493	·0979	+73·42
2	48·7925	......	......	......	2	11·4509	......	......	......
1	46·1133	46·1000	·1128	118·55					

Weighted mean.......	+ 78·03
V_a	− 20·91
V_d	− ·21
Curvature..................	− ·28
Radial velocity..	+ 56·6

‡ Second check measurement. Accepted result + 55·9.

θ AQUILAE 1050.

1907. Sept. 18.
G. M. T- 14h 45m

Observed by} J. N. TRIBBLE.
Measured by}

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	73·0318	......	......	......	2	45·2738	......	......	......
1	72·8699	72·8031	·0156	−22·66	1½	45·2139	45·2237	·0250	−26·17
2	72·4635	......	......	......	2	27·2441	......	......	......
2	54·0294	......	......	......	½	27·3813	27·4591	·0374	−32·59
1	53·9742	53·9601	0035	+4·03					

Weighted mean............	− 26·06
V_a	− 22·14
V_d	− ·14
Curvature.............	− ·28
Radial velocity..............	− 48·6

θ AQUILAE 1072.

1907. Sept. 30.
G. M. T. 13h 02m

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9873	...	...	...	1½	45·2684	45·2689	·0202	21·15
2	72·8666	72·8424	·0237	+34·34	¼	27·4692	27·5017	·0052	4·53
2	72·4250	...	...	...	2	27·2893	...	...	...
2	54·0275	...	...	...	1¼	11·9493	11·0422	·0418	+31·35
2	53·9952	53·9830	·0264	30·46	2	11·5641	...	...	...
2	45·2831	...	...	...					

Weighted mean...... +28·83
V_a .... −25·32
V_d .... − ·04
Curvature...... .... − ·28

Radial velocity...... + 3·2

θ AQUILAE 1073.

1907. Sept. 30.
G. M. T. 13h 25m

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9938	...	...	...	2	45·2805	...	...	...
1	72·8648	72·8426	·0240	+34·87	1½	45·2685	45·2716	·0240	25·13
2	72·4273	...	...	...	1	11·9490	12·0322	·0318	+23·85
2	54·0241	...	...	...	2	11·5750	...	...	...
2	53·9952	53·9864	·0298	34·39					

Weighted mean...... +30·03
V_a .... −25·32
V_d .... − ·08
Curvature.............. − ·28

Radial velocity....... + 4·3

θ AQUILAE 1074.

1907. Sept. 30.
G. M. T. 14h 08m

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9713	...	...	...	2	45·2615	...	...	...
2	72·8370	72·8278	·0091	+13·22	1	45·2597	45·2818	·0331	34·65
2	72·4130	...	...	...	½	27·4604	27·5093	·0128	11·16
2	57·8042	...	...	...	2	27·2730	...	...	...
1	57·8319	57·8256	·0209	25·20	1	11·9371	12·0378	·0374	+28·05
2	54·0157	...	...	...	2	11·5564	...	...	...
2½	53·9683	53·9680	·0114	13·15					

Weighted mean. ..... +19·10
V_a .... −25·32
V_d .... — ·12
Curvature .... — ·28

Radial velocity ... . — 6·6

θ AQUILAE 1080.

1907. Oct 1.
G. M. T. $12^h\ 03^m$

Observed by W. E. HARPER.
Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	54·0475	....	....	....	½	45·3006	45·2736	·0349	36·42
1½	54·0344	54·0157	·0459	+52·82	2	11·5949	....	....	....
2	45·3007	....	....	....	1	12·0235	11·9358	·0844	+63·26

Weighted mean....... +53·56
V_a .... −25·51
V_d .... 0·0
Curvature .... ·28

Radial velocity .... + 27·8

θ AQUILAE 1081.

1907. October 1.
G. M. T. $12^h\ 32^m$

Observed by W. E. HARPER.
Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	72·9728	....	....	....	2	27·2640	....	....	....
2	54·0051	....	....	....	½	27·4461	27·5040	·0075	6·53
2	54·0046	54·0146	·0580	+66·91	1½	11·5483	....	....	....
2	45 2637	....	....	....	2	11·9684	12·0781	·0777	58·55
1	45·2717	45·2917	·0430	45·01					

Weighted mean...... +59·18
V_a .... −25·51
V_d .... − ·04
Curvature.............. − ·28

Radial velocity....... + 33·3

θ AQUILAE 1082.

1907. October 1.
G. M. T. $13^h\ 09^m$

Observed by W. E. HARPER.
Measured by J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	73·0048	....	....	....	2	27·3045	....	....	....
1½	72·4420	....	....	....	½	27·5159	27·5333	·0368	32·07
1	72·8770	72·8352	·0165	+23·97	2	15·4790	....	....	....
2	54·0435	....	....	....	¼	15·5842	15·6342	·0307	23·89
2	54·0466	54·0186	·0620	71·52	2	11·5926	....	....	....
2	45 2984	....	....	....	¾	12·0295	11·9441	·0945	+71·15
1	45·2929	45·2781	·0294	30·78					

Weighted mean...... +52·95
V_a.................... −25·54
V_d .... − ·04
Curvature.............. − ·50

Radial velocity....... + 26·9

θ AQUILAE 1082.*

1907. Oct. 1.
G. M. T. 13h 09m

Observed by W. E. HARPER.
Measured by J. S. PLASKETT.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9676	.....	.....	.....	2	54·0063	54·0177	·0611	70·51
2	72·4047	.....	.....	.....	1½	53·0897	.....	.....	.....
2	59·7820	.....	.....	.....	3	45·2612	.....	.....	.....
½	59·6931	59·6941	·0455	+56·10	2	27·2676	.....	.....	.....
1	57·8570	57·8573	·0526	63·43	1	11·9818	12·0855	·0851	+64·08
1	57·7976	.....	.....	.....	2	15·4432	.....	.....	.....
2	54·7148	.....	.....	.....	2	11·5524	.....	.....	.....

Weighted mean...... +60·6
V_a .... −25·54
V_d .... − ·04
Curvature .... − ·50

Radial velocity....... + 34·5

* Check measurement.

θ AQUILAE 1082.‡

1907. Oct. 1.
G. M. T. 13h 09m

Observed by, Measured by W. E. HARPER.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9803	.....	.....	.....	2	54·0219	.....	.....	.....
½	72·8630	72·8922	·0274	+39·76	3	54·0131	54·0210	·0512	58·93
2	72·4168	.....	.....	.....	2	52·2388	.....	.....	.....
2	59·7975	.....	.....	.....	2	45·2724	.....	.....	.....
½	59·6978	59·7095	·0350	43·05	½	45·2852	45·2864	·0477	49·80
1	57·8638	57·8736	·0468	56·35	1	11·9972	11·9400	·0886	+66·45
2	57·8102	.....	.....	.....	2	11·5646	.....	.....	.....

Weighted mean...... +56·20
V_a .... 25·54
V_d .... − ·04
Curvature .... − ·50

Radial velocity. .... + 30·1

‡ Second check measurement; accepted result +30·5.

θ AQUILAE 1085.

1907. Oct. 1.
G. M. T. 11h 43m

Observed by } W. E. Harper.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9545	....	....	....	1	53·2139	53·2514	·0376	42·98
1½	72·8310	72·8400	·0213	+30·78	2	53·0630	....	....	....
2	72·3912	....	....	....	2	45·2322	....	....	....
½	57·8245	57·8460	·0413	49·77	1½	45·2464	45·2978	·0491	51·30
2	57·7764	....	....	....	½	27·4664	27·5434	·0469	40·63
1	53·9827	53·0171	·0605	69·81	2	27·2446	....	....	....
1½	53·9809	....	....	....	1½	11·9660	12·0960	·0956	+71·25
1	53·1007	53·1382	·0381	43·55	2	11·5280	....	....	....

Weighted mean..............	+50·77	
V_a		−25·54
V_d		− ·17
Curvature..................		− ·28
Radial velocity	+24·8	

θ AQUILAE 1086.

1907. Oct 1.
G. M. T. 15h 24

Observed by } J. N. Tribble.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9723	....	....	....	1½	45·3057	45·3151	·0664	69·51
½	72·8482	72·8395	·0208	+30·22	2	27·2818	....	....	....
1½	54·0143	....	....	....	½	27·5220	27·5620	·0655	57·08
1½	54·0087	54·0097	·0531	61·26	2	11·5682	....	....	....
2	45·2742	....	....	....	2	11·9990	12·0888	·0884	+66·61

Weighted mean..............	+62·17	
V_a		−25·54
V_d		− ·21
Curvature..................		− ·50
Radial velocity	+35·9	

θ AQUILAE 1089.

1907. Oct. 2
G. M. T. $12^h\ 41^m$

Observed by } J. N. TRIBBLE.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9608	....	....	....	1½	45·2951	45·2951	·0464	48·57
½	72·8377	72·8405	·0218	+31·67	1	27·4772	27·5416	·0451	39·31
2	54·0010	....	....	....	1½	27·2575	....	....	....
2	53·9840	53·9983	·0417	48·10	1	11·9407	12·0554	·0550	-41·45
2	45·2537	....	....	....	1½	11·5433	....	....	....

Weighted mean...... +44·41
V_a .... −25·73
V_d .... − ·04
Curvature.................. − ·50

Radial velocity....... + 18·1

θ AQUILAE 1091.

1907. Oct. 2.
G. M. T. $13^h\ 40^m$

Observed by } J. N. TRIBBLE.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	54·0710	....	....	....	1	45·3326	45·2808	·0421	43·94
2	54·0705	54·0283	·0585	+67·32	2	12·0140	11·9121	·0607	+45·50
2	45·3254	....	....	....	2	11·6091	....	....	....

Weighted mean...... +53·91
V_a .... −25·73
V_d .... − ·11
Curvature.................. − ·28

Radial velocity. ..... + 27·8

θ AQUILAE 1092.

1907. Oct. 2
G. M. T. $14^h\ 08^m$

Observed by } J. N. TRIBBLE.
Measured by }

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9697	....	....	....	1	45·2606	45·2871	·0384	40·20
½	72·8425	72·8365	·0178	+25·86	1½	27·2645	....	....	....
2	54·0015	....	....	....	½	27·4768	27·5342	·0377	32·86
2	53·9898	54·0038	·0472	54·45	1	11·9760	12·0890	·0886	+66·76
2	45·2573			....	2	11·5531	....	....	....

Weighted mean...... +49·04
V_a .... −25·73
V_d .... − ·16
Curvature.................. − ·28

Radial velocity..... +22·9

θ AQUILAE 1093.

1907. Oct. 2.
G. M. T. $14^h\ 36^m$

Observed by, Measured by } J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9961				1½	45·3075	45·2915	·0528	55·10
½	72·8785	72·8920	·0272	+39·47	1½	27·2982			
2	54·0407				½	27·4859	27·4543	·0324	28·12
3	54·0354	54·0234	·0536	61·68	½	11 9606	11·8843	·0329	+24·66
2	45·2894				2	11·5835			

Weighted mean...... +52·30
V_a .... —25·73
V_d .... — ·19
Curvature .... — ·28

Radial velocity....... +26·1

θ AQUILAE 1094.

1907. Oct. 2.
G. M. T. $14^h\ 59^m$

Observed by, Measured by } J. N. TRIBBLE.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	53·8927				2	45·1453			
1	53·8621	53·9712	·0280	+32·38	½	45·1570	45·3053	·0464	+48·72

Weighted mean....... +37·82
V_a .... −25·74
V_d .... − ·21
Curvature................ − ·28

Radial velocity.... ...... +11·6

θ AQUILAE 1100.

1907. Oct. 18.
G. M. T. $12^h\ 15^m$

Observed by, Measured by } W. E. HARPER.

Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W.L.	Displacement.	Velocity.
61·3792					61·3520	4482·246	.400	·846	+56·59

Velocity......... ..... +56·59
V_a .... −28·00
V_d .... − ·18
Curvature............... − ·28

Radial velocity...... +28·1

θ AQUILAE 1101.

1907. Oct. 18.
G. M. T. 13h 46m

Observed by / Measured by } W. E. HARPER.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
71·9841	4550·581	·766	·815	+53·71	61·3936	4482·390	·400	·990	66·23
71·8433	.....	.....	.....	.....	58·8306	.....	.....	.....	.....
63·3795	.....	.....	.....	.....	36·1916	.....	.....	.....	.....
61·3974	.....	.....	.....	.....	36·2390	4341·404	·634	·770	+53·13

Weighted mean....... + 61·46
V_a .... −28·00
V_d .... − ·18
Curvature .... ·28

Radial Velocity........ + 33·0

θ AQUILAE 1106.

1907. Oct. 25.
G. M. T. 12h 52m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Measured Wave Length.	Normal W. L.	Displacement.	Velocity.
111·1159	.....	.....	.....	.....	61·3286	.....	.....	.....	.....
110·7355	4861·323	·527	·204	−12·59	61·1051	4481·089	·400	·311	20·81
109·7163	.....	.....	.....	.....	60·3136	.....	.....	.....	.....
71·7697	.....	.....	.....	.....	36·1414	.....	.....	.....	.....
71·6947	4549·192	·642	·450	29·65	36·0162	4340·548	·634	·086	5·94
71·1525	.....	.....	.....	.....	35·3590	.....	.....	.....	.....

Weighted mean............. − 15·59
V_a .... − 28·34
V_d .... − ·16
Curvature .... − ·28

Radial velocity............. − 44·4

θ AQUILAE 1128.

1907. Nov. 4. G. M. T. $10^h\ 28^m$

Observed by J. S. Plaskett. Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
½	57·9161	57·8810	·0542	+65·26	2½	45·2960	45·2707	·0320	35·41
1	57·8551	...	...	...	2	27·4995	27·4708	·0489	42·44
2	54·7672	...	...	...	2	27·2753	...	...	...
1½	54·0426	54·0150	·0452	51·66	1½	11·9303	11·9146	·0632	47·59
2	53·1401	...	...	...	2	11·5229	...	...	...
2	45·2990	...	...	...					

Weighted mean	+44·36	
V_a		−28·10
V_d		0·0
Curvature		·28
Radial velocity	+16·0	

θ AQUILAE 1129.

1907. Nov. 4. G. M. T. $10^h\ 51^m$

Observed by J. S. Plaskett. Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	73·0432	...	...	...	2	45·2935	...	...	...
1½	72·9345	72·9[illegible]02	·0354	+51·36	2	45·3185	45·2987	·060[illegible]	62·6
2	72·4820	...	...	...	1½	27·5148	27·4855	·0636	[illegible]5·20
2	54·7632	...	...	...	2	27·2760	...	...	...
1½	54·0495	54·0265	·0567	64·81	1½	11·9599	11·9419	·0905	+68·15
2	53·1355	...	...		2	11·5250	...	...	...

Weighted mean	+60·57	
V_a		−28·10
V_d		− ·04
Curvature		·28
Radial velocity	+32·1	

θ AQUILAE 1146.

1907. Nov. 16. G. M. T. $12^h\ 00^m$

Observed by J. S. Plaskett. Measured by C. R. Westland.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1½	72·9782	...	...	...	2	53·1068	...	...	...
½	72·8285	72·8597	·0051	− 7·40	2	45·2699	...	...	...
1½	72·4148	...	...	...	1½	45·2301	45·2338	·0050	5·22
2	54·7330	...	...	...	1	27·4294	27·4055	·0164	−14·23
1½	53·9521	53·9546	·0152	17·49	2	27·2705	...	...	...

Weighted mean	−11·55
V_a	−26·09
V_d	− ·16
Curvature	− ·28
Radial velocity	− 38·1

θ AQUILAE 1149.

1907. Nov. 18.
G. M. T. $10^h\ 45^m$

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9731	....	....	....	2½	53·9463	53·9661	·0037	− 4·26
1	72·8456	72·8806	·0158	+22·92	2	53·0907	....	....	....
1½	72·4152	....	....	....	2	45·2630	....	....	....
2	54·7233	....	....	....	1½	45·2529	45·2635	·0248	+25·89

Weighted mean..........	− 4·26
V_a....................	−26·34
V_d....................	− ·20
Curvature...............	− ·28
Radial velocity........	−31·1

θ AQUILAE 1150.

1907. Nov. 18.
G. M. T. $12^h\ 37^m$

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9724	....	....	....	2	45·2649	....	....	....
2	72·8351	72·8726	·0078	+11·31	1½	45·2280	45·2367	·0020	− 2·09
2	72·4071	....	....	....	½	27·4435	27·4268	·0049	+ 4·25
2	54·7197	....	....	....	2	27·2633	....	....	....
3	53·9560	53·9772	·0074	+ 8·52	2	11·8985	11·8635	·0124	+ 9·07
1½	53·0919	....	....	....	2	11·5420	....	....	....

Weighted mean...... + 7·25	
V_a....................	−26·34
V_d....................	− ·22
Curvature...............	− ·28
Radial velocity........	−19·6

θ AQUILAE 1154.

1907. Nov. 19.
G. M. T. $10^h\ 41^m$

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	72·9641	....	....	....	1½	53·0724	....	....	....
2	72·8238	72·8696	·0048	+ 6·96	2	45·2360	....	....	....
2	72·3987	....	....	....	2	45·2065	45·2400	·0013	+ 1·36
2	54·7009	....	....	....	½	27·3975	27·4130	·0089	− 7·72
1½	53·9512	53·9930	·0232	+26·70	2	27·2311	....	....	....

Weighted mean...... + 8·89	
V_a....................	−26·46
V_d....................	− ·11
Curvature...............	− ·28
Radial velocity........	−18·0

θ AQUILAE 1155.

1907. Nov. 19.
G. M. T. 11h 00m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
1	73·0047	....	....	....	2½	53·9832	53·9671	·0027	— 3·11
1½	72·8657	72·8691	·0043	+ 6·24	2	53·1303	....	....	....
½	72·4465	....	....	....	2	45·2904	....	....	....
2	54·7551	....	....	....	1½	45·2421	45·2253	·0134	—13·99

Weighted mean........	— 3·53
V_a	—26·46
V_d	— ·14
Curvature	— ·28
Radial velocity........	—30·4

θ AQUILAE 1157.

1907. Nov. 23.
G. M. T. 12h 42m

Observed by J. S. PLASKETT.
Measured by C. R. WESTLAND.

Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.	Wt.	Mean of Settings.	Corrected Star Settings.	Displacement in Revns.	Velocity.
2	73·0462	....	....	....	1½	53·9209	53·9616	·0082	9·42
1½	72·9000	72·8643	·0005	— 0·73	2	53·0706	....	....	....
2	72·4785	....	....	....	2	45·2005	....	....	....
2	54·7020	....	....	....	1	45·1587	45·2315	·0072	— 7·52

Weighted mean........	— 5·69
V_a	—26·94
V_d	— ·26
Curvature	— ·28
Radial velocity........	—33·2

SUMMARY OF MEASURES OF η AQUILAE.

Plate Number.	Date.		G. M. T.		Julian Day.	Phase.	Velocity.	Plate Number.	Date.		G. M. T.		Julian Day.	Phase.	Velocity.
	1907.		h.	m.					1907.		h.	m.			
803	May	31	19	04	2,417,727·79	0·79	−24	1073	Sept.	30	13	25	2,417,849·56	2·37	+ 4
819	June	10	19	40	737·81	10·81	39	1074	"	30	14	08	849·58	2·39	− 7
841	"	12	20	05	739·84	12·84	−38	1080	Oct	1	12	03	850·50	3·31	+28
854	"	14	19	36	741·82	14·82	−42	1081	"	1	12	32	850·52	3·33	+33
865	"	20	18	40	747·78	3·61	+45*	1082	"	1	13	09	850·54	3·35	+30*
873	"	21	19	20	748·80	8·63	−32*	1085	"	1	14	43	850·61	3·42	+25
905	July	2	18	12	759·76	15·59	−40	1086	"	1	15	24	850·64	3·45	+36
924	"	8	18	37	765·77	4·43	−22*	1089	"	2	12	41	851·53	4·34	+18
931	"	9	17	05	766·71	5·37	−29	1091	"	2	13	40	851·57	4·38	+28
942	"	13	16	53	770·70	9·36	−38*	1092	"	2	14	08	851·58	4·39	+23
946	"	16	17	07	773·71	12·37	−43	1093	"	2	14	36	851·61	4·42	+26
959	"	20	18	19	777·76	16·42	−45	1094	"	2	14	59	851·62	4·43	+12
969	"	27	18	15	784·76	6·25	−40	1100	"	18	12	15	867·51	3·15	+28
1001	Aug.	10	15	50	798·66	2·98	+19	1101	"	18	13	46	867·57	3·21	+33
1012	"	13	16	37	801·69	6·01	39	1106	"	25	12	52	874·53	10·17	44
1013	"	15	13	45	803·57	7·89	−51*	1128	Nov.	4	10	28	884·44	2·91	+16
1023	"	23	16	10	811·67	15·99	−22	1129	"	4	10	51	884.45	2·92	+32
1027	"	27	16	04	815·67	2·82	+11*	1146	"	16	12	00	896·50	14·97	−38
1028	"	27	15	07	815·63	2·78	+10	1149	"	18	10	45	898·45	16·92	−31
1033	Sept.	6	14	41	825·61	12·76	−37*	1150	"	18	12	37	898·53	17·00	−20
1038	"	12	15	15	831·63	1·61	−16*	1154	"	19	10	41	899·45	0.75	−18
1043	"	14	16	10	833·67	3·65	+56*	1155	"	19	11	00	899·46	0.76	−30
1050	"	18	14	45	837·61	7·59	−49	1157	"	23	12	42	2,417,903·53	4·83	−33
1072	"	30	13	02	849·54	2·35	+ 3								

* Mean of two or three measurements.

APPENDIX C.

MEASUREMENT OF VISUALLY DOUBLE STARS.

R. M. MOTHERWELL.

The 15-inch refractor with a filar micrometer (see report of 1905) is used in this work. The micrometer is fitted with one transverse movable wire, one transverse fixed wire and one longitudinal fixed wire. The distance between the fixed and movable transverse wires is adjusted and recorded by a micrometer screw having a head graduated to hundredths of a revolution and readily estimated to thousandths. The value of a revolution of the micrometer screw is determined as follows:—

The telescope is set on a star of known declination near the meridian. The micrometer is adjusted so that the star follows the longitudinal wire and the movable wire is separated M revolutions from the central fixed wire. The times of the successive transits of the star over the two wires are observed. Let I be the interval between these transits, i the true angular interval between the threads and δ the declination of the star. Then

$$\sin i = \sin I \cos \delta$$

or if the star's declination is less than + 80°

$$i = I \cos \delta$$

Let R = value of one revolution of the micrometer screw and we have

$$R = \frac{15\,i}{M} = \frac{15\ I \cos \delta}{M}$$

Following this method the value of the micrometer screw here used was found to be 18″·375.

The zero point of the circle is always determined at the beginning of each night's work.

The position angle is obtained by separating the wires a few seconds and turning them until the two stars appear to be midway between them. If the stars are very far apart, however, the angle is more accurately obtained by bisecting each star by the fixed wire. The eyes must be kept in a constant position relative to the fixed wire. I find the best position to be that in which the line joining the eyes is perpendicular to the fixed wire. Having taken four readings of the position angle, the wires are rotated through 180° and four readings of the angle taken here.

The average of these readings plus 90° gives the direction of the wires for measuring the distance. The stars are bisected by the two wires and the micrometer reading taken. Then the movable wire is changed to the other side of the fixed wire, the stars bisected as before and the reading taken. The difference between the two readings gives the double distance which does away with the necessity of investigating the error of runs. The measurements on a star any one night include eight measurements for position and at least four for distance. If the seeing is unsteady the number of measurements is increased. A full record of all stars measured is kept on a special form of index card, arranged according to the right ascension of the star. Burnham's General Catalogue of Double Stars furnishes in condensed form all the information required to enable this work to be carried on without unnecessary duplicating of measurements.

The following measurements have been made:—

Date.	Star No.*	R. A. 1880.	Decl. 1880.	Position Angle.	Distance.	Magnitude.
		h. m. s.	° ′		″	
1907·814	70	0 7 11	26 19	224·3	17·75	A.B. & C.
1907·92	319	0 29 16	11 11	11·0	61·07	8·5-10·5
1907·92	710	1 13 54	13 8	190·2	30·20	8·5 10·
1907·790	758	1 20 29	44 47	100·1	2·15	A. & B.
				136·2	4·85	C. & D.
1907·814	1002	1 48 17	28 13	162·8	5·88	A. B. & C.
1907·812	1427	2 40 41	18 52	315·7	3·07	7·3 8·2
1907·92	1750	3 25 37	11 8	248·3	17·04	7·5–10
1907·92	2040	4 0 54	14 50	222·6	3·95	6· 8·5
1907·812	2043	4 1 7	17 1	323·7	4·03	6·1–9·2
1908·116	5014	9 11 23	37 19	231·7	3·00	4· 6·5
1908·217	7117	14 59 10	-6 33	305·8	1·88	8· 9·
1908·217	7210	15 12 57	10 52	170·4	14·46	6·5–7
1908·217	7318	15 29 5	10 56	184·5	3·90	3·–4·
1907·543	7915	17 9 12	28 57	18·5	5·50	7·8-9·5
1907·543	8003	17 19 33	37 15	314·5	4·00	4· 5·1
1907·491	8082	17 30 52	21 4	23·77	10·22	6·0-9·5
1907·510	8303	17 56 33	–8 11	260·2	2·09	5·-5·5
1907·491	9167	19 11 7	27 15	156·15	0·78	6·5 7·
1907·491	9604	19 41 3	5 52	7·5	2·96	8·5-10
1907·530	9693	19 47 19	25 33	136·9	3·98	7·6–7·6
1907·576	10072	20 12 31	26 0	215·0	0·73	7·9-8·2
1907·600	10305	20 26 50	25 24	81·9	1·29	6·2 8·
1907·71	10385	20 33 14	14 35	112·7	3·38	8· 10·5
1907·584	10685	20 56 58	1 4	161·7	1·37	6·3 7·
1907·587	10709	20 58 43	3 3	160·2	3·35	7·7–8·9
1907·543	10773	21 3 33	29 43	307·0	3·5	6·–8·
1907·576	10910	21 14 51	2 37	106·0	1·59	7·6–9·5
1907·697	11068	21 29 40	20 52	320·0	1·7	7·1–9·0
1907·697	11376	21 51 11	51 58	27·0	1·85	7·8–8·0
1907·697	12043	22 48 45	19 42	35·0	6·52	8·5 9·2
1907·71	12345	23 18 14	5 23	87·3	2·37	8·7-8·7
1907·71	12753	23 59 49	6 12	161·8	3·12	9· 9·5

PREDICTION AND OBSERVATION OF OCCULTATIONS.

The method which I have followed in predicting occultations is a graphic one by Wm. F. Rigge, and I find it very satisfactory. It eliminates entirely all the laborious computing of the analytical method, and in central occultations the predicted and observed times seldom differ more than 30 or 40 seconds.

In this method the path of the place of observation and that of the cylindrical shadow cast by the moon in the light of the star are projected orthographically on a plane perpendicular to the light of the star. The diagram for a given place of observation contains the path of that place as seen from stars at certain intervals of declination from + 30° to – 30°. The path is an ellipse with the following constants, where ϕ is the latitude of the place, δ the declination of the star and T its hour angle. The semi-major axis is the same for all stars, $a = \cos \phi$; the semi-minor axis is $b = \cos \phi \sin \delta$; the co-ordinate of the centre of each is $d = \sin \phi \cos \delta$. The co-ordinates of the points of any one are $\xi = a \sin T$ and $\eta = d - b \cos T$. The direction and magnitude of the hourly motion of the shadow of the moon are obtained from the Ephemeris and plotted on the x and y axes of the diagram with a paper edge. A parallel ruler is then placed against the paper edge and moved until it intersects the y-axis at the proper point, as given by the Ephemeris.

The local hour angle of conjunction, $H - \lambda$, gives the time at which the path of the shadow intersects the y-axis, so we have the position of the place of observation and that of the shadow at known periods. A transparent disc represents the shadow

* These numbers refer to Burnham's General Catalogue of Double Stars.

and is moved so that its centre follows the path given. When the time indicated on the path by the centre of the disc is the same as the time indicated on the path of the place of observation by the edge of the disc, we have the beginning or ending of an occultation. This time added to the Washington mean time of conjunction minus the Washington hour angle at the same moment gives the time of immersion or emersion and the position angle is read directly from the disc which is graduated clockwise to 10 degrees. A diagram has been prepared for this observatory and mounted on a drawing board for convenience in working. Not more than 10 minutes at the very outside is required to predict the times of immersion and emersion and also the position angles.

The 15-inch refractor fitted with a filar micrometer is generally used in making the observations, but if more convenient the 4½-inch refractor is used. The time is taken from a sidereal dial which has recently been placed in the dome, this dial being compared with the sidereal clock of known rate in the time-room.

Since September 1, 1907, fifty-seven occultations have been predicted, but, owing to cloudy weather, only twelve have been observed.

The following are the stars and dates of observation:—

Date.	Star.	Magnitude.	Sidereal Time. Immersion.	Sidereal Time. Emersion.
1907.			h. m. s.	h. m. s.
September 14	ξ Ophiuchi	4·4	19 56 27·5	20 35 22·0
October 15	η Capricorni	4·8	Sun not down.	19 43 18·7
" 21	85 Ceti	6·3	7 56 0·2	Sunrise.
" 23	δ¹ Tauri	3·9	7 24 10·8	8 3 17·2
" 23	δ³ Tauri	4·3	8 31 57·9	Sunrise.
" 23	δ Geminorum	3·5	1 24 27·0	2 16 23·0
1908.				
January 8	30 Piscium	4·7	1 24 30·0	Clouds.
" 14	Mayer 198	6·3	4 30 34·9	5 45 1·2
" 14	107 Tauri	6·5	7 11 32·9	7 37 18·5
" 29	B. A. C. 6088	5·7	14 17 50·8	15 19 47·0
February 11	ζ Tauri	3·0	2 50 11·5	4 9 40·0
March 19	α Virginis	6·5	16 36 30·0	17 45 4·0

APPENDIX D.

A DETERMINATION OF THE PROMINENT LINES FROM λ 3900 TO λ 4900. IN THE SPARK-SPECTRUM OF IRON-VANADIUM ALLOY.

Ralph E. DeLury.

The spectrum of the spark between electrodes of an Iron-Vanadium alloy is employed in this Observatory as a comparison in the study of radial velocities. The tables of wave-lengths used are:—

H. Kayser:—'*Standard Lines in the Arc-Spectrum of Iron,*' Astrophysical Journal, XIII, 329-335, 1901. The portion of this table employed is from λ 3900 to the end, λ 4494.

H. A. Rowland:—'*A Preliminary Table of Solar Spectrum Wave-Lengths,*' the University of Chicago Press, 1896. Some of the iron lines from λ 4494 to λ 4900 are used.

H. A. Rowland and C. N. Harrison:—'*The Arc-Spectrum of Vanadium,*' Astrophysical Journal, VII, 273-294, 1898. The prominent lines in the range, λ 3900 to λ 4900 are used.

In the latter table some of the wave-lengths given do not yield results concordant with those obtained by using the Standard Iron lines determined by Kayser. In some cases this is due to the over-lapping of Iron and Vanadium lines; or possibly some of the lines in the spark-spectrum of the alloy may differ from the corresponding lines in the arc-spectrum of pure Vanadium. In order to detect any such appreciable errors, to measure such differences and to examine the nature of the over-lappings, the following measurements of the spark-spectrum of Iron-Vanadium alloy were undertaken.

The concave grating spectroscope described on page 49 of the report for the year ending June 30, 1906, was used in obtaining the spectrum. In order to secure suitable definition certain adjustments were necessary. The angle between the rails was determined by measuring the lengths from their points of intersection, of the wires stretched taut by weights along the tops of the rails and another wire (the hypothenuse) intersecting these near the ends of the rails. It was found that the hypothenuse had to be shortened 6·5 mm. to make the angle between the rails a right angle. This was done by tilting the iron-support of the rail on which the camera rested, and by the adjusting-screws. Then the position for the slit was determined by using a plumb-bob suspended from the ceiling above the point where the two wires running along the rails intersected. The jaws of the slit were improved by grinding them on plate-glass with moistened fine emery dust. The slit was placed as nearly vertical as possible, and by testing visually, the lines of the grating were made parallel to it by means of the adjusting-screw on the side of the grating-mounting. The grating was tilted, by means of the adjusting-screw at the back of the mounting until its centre of curvature coincided with the centre of the eye-piece, by using a collimating (Gauss) eye-piece. It was found that the centre of curvature shifted slightly vertically when the camera was slid along the rail and consequently the adjusting-screw at the back of the grating was provided with a pointer so that it could be set for any point along the rail to insure having the image of the spectrum placed to the best advantage. In this position the lines of the grating and the slit were

perpendicular to the plane determined by the centre of the slit, the centre of the grating and the centre of curvature of the grating. Numerous tests were made to secure these conditions and to get the best focus. A focussing-scale was placed on the plate of the camera support. The wave-lengths were marked off along the rail.

The spark between electrodes of the alloy was obtained by using a potential of 5,000 to 7,000 volts from a transformer. It was placed about 6 inches from the slit and the light from it was focussed on the slit by a small lens, care being taken to have the spark, the centre of the slit and the centre of the grating as nearly as possible in a straight line in order to secure the best illumination. The spark passed at right angles to the slit. Slit-widths of 0·001 and 0·002 inches were used. The photographs, 9 to 12 inches long, were taken in the second order, Ilford Monarch films being employed. The scale here is about 2·77 tenth-metres to 1 mm. Exposures of 20 to 40 minutes brought out sharply the prominent lines. Several photographs were taken at different foci for the various parts of the spectrum, and the sharpest of these (focus 7·0) selected for measurement. It was noticed here that some of the photographs of the image when out of focus gave sharp doubled lines probably due to the shifting of the centre of intensity of the spark due to the alternations, since a corresponding doubling did not occur in carbon arc photographs taken at different readings on the focussing scale. It was found that these doubled lines could be measured by placing the single hair of the microscope between them with more accuracy and with less strain on the eyes than is the case in the ordinary methods, namely, by using a single hair to set on the centre of intensity of the spectrum line or by using the double hairs to set symmetrically about the spectrum line. It may be of advantage in certain cases to use a doubled spectrum for the determination of the lines. In the present case, however, the other two methods of measurement mentioned above, were employed on account of the fact that many close doubles and overlapped lines had to be measured and this would be impossible in the case of the doubled spectrum. In these measurements a Zeiss comparator having a range of 100 mm. was used. This range is rather short for the measurement of such long films, and the new 12-inch measuring machine will be useful for this purpose when it arrives. Readings of the micrometer could be made to 0·001 mm. and estimations to 0·0001 mm. Four or more readings were taken for each line and the average calculated.

The wave-lengths were calculated from the averages of the micrometer readings by interpolation and extrapolation using two prominent lines to determine the scale. These two lines were iron lines in every case and are given in black type in the tables. The calculated wave-lengths were compared with Standard Iron lines, and a curve of errors plotted for each set of measurements. From this curve the corrections given in the tables were found. Applying these corrections to the calculated wave-lengths, the corrected wave-lengths given in the tables were determined. A summary is given in the final table. The means of the corrected wave-lengths are given along with the corresponding lines from the tables of Rowland and Harrison, Rowland and Kayser mentioned above. In determining the means, those wave-lengths marked with an asterisk were omitted. In this table are also given the roughly estimated intensities of the lines and remarks as to their nature and the widths of the lines in millimetres. These widths were determined by comparison with two parallel lines 0·1 mm. apart. These measurements of intensity and width were made from photographs obtained by the use of a slit ·001 inch in width. No lines of intensity less than 1 on the arbitrarily selected scale were measured; this meant that about 500 of the lines appearing on the film were omitted. Figure 15 shows photographs of the range of spectrum measured.

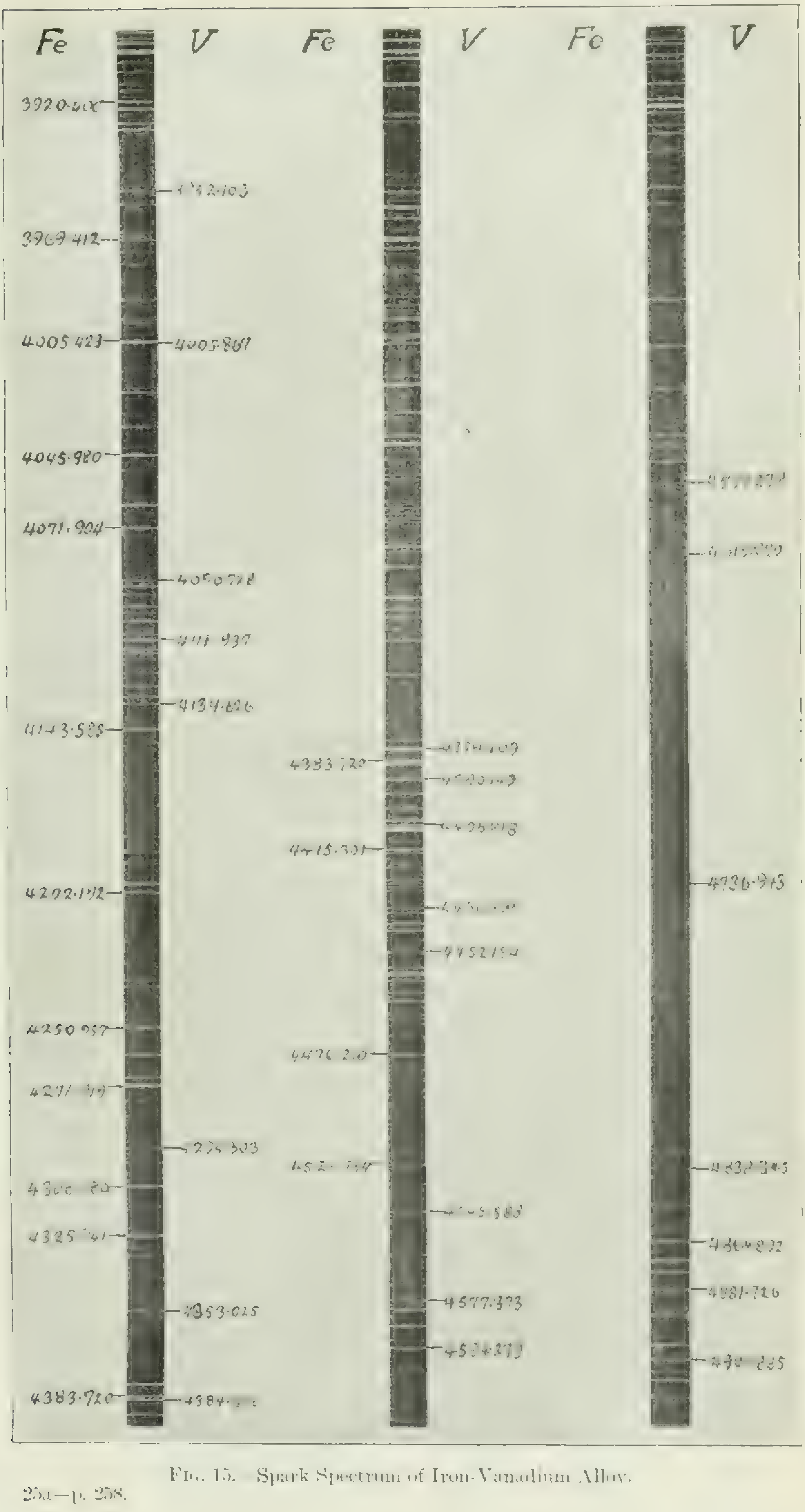


Fig. 15.—Spark Spectrum of Iron-Vanadium Alloy.

Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.
Film 265 (a), Focus 7·0							
− ·002	3895·801						
2	3898·100						
2	3899·283						
2	3899·853						
0	3902·408						
·000	**3903·097**						
0	3903·412						
1	3906·588						
3	3910·028						
6	3914·469						
7	3916·574	Film 412 (a), Focus 7·0					
10	3920·407	·000	**3920·404**				
9	3923·059	− ·013	3923·054				
14	3928·072	27	3928·077				
16	3930·433	32	3930·459				
17	3933·815						
		36	3934·151				
		45	3948·920				
		45	3950·101				
22	3952·110	46	3952·095				
		46	3956·642				
22	3956·824	46	3956·848				
		45	3966·754				
		44	3967·575				
21	3968·244	44	3968·230				
21	3968·634						
21	3969·409	44	3969·414				
20	3973·799	43	3973·781				
19	3977·893	42	3977·899				
		40	3984·123				
16	3990·726	37	3990·720				
		36	3992·954				
14	3997·275	34	3997·274				
14	3997·553	34	3997·564				
14	3998·881	34	3998·608*	Film 265 (a), Focus 7·0			
				+ ·007	4003·159		
12	4005·399	31	4005·436	7	4005·451		
		29	4009·885				
		26	4014·697				
		22	4022·044				
6	4023·536	21	4023·548	4	4023·581		
− ·002	4035·782	15	4035·788	2	4035·818		
+ ·002	4045·978	10	4045·984	·000	**4045·978**		
		7	4051·130				
		7	4051·499				
		4	4057·244				
		2	4061·069				
		2	4062·626				
7	4063·756	− ·001	4063·752	− ·004	4063·759		
				4	4065·229		
18	4071·909	+ ·002	4071·908	2	4071·894		
4	4090·724			0	4090·731		
		6	4091·287				
4	4092·831	5	4092·853	1	4092·836		
3	4095.638	5	4095·645	1	4095·626		
+ ·001	4099·943	4	4099·939	2	4099·932		
		3	4102·312	3	4102·300		
− ·001	4105·310	+ ·002	4105·319	3	4105·311		
		0	4107·641	4	4107·646		
3	4109·919	− ·002	4109·921	5	4109·915		
4	4111·934	3	4111·938	5	4111·939		
5	4115·323	5	4115·310	7	4115·334		
5	4116·646	5	4116·644	8	4116·648		
5	4118·711	6	4118·710	9	4118·709		
5	4123·651	6	4123·645	8	4123·657		
5	4128·211	5	4128·821	7	4128·211		
− ·004	4132·180	− ·003	4132·163	− ·005	4132·180		

Correction.	Corrected Wave Length.	Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.
...	...	− ·003	4134·613	...	...	...	...
− ·003	*4134·104	3	4134·626	− ·003	4134·655	...	...
...	...	3	4134·860	...	...	...	...
0	4143·599	0	4143·566	+ ·001	4143·595	...	...
000	**4144·033**	·000	**4144·033**	+ ·002	4144·033	...	...
Film 401, Focus 7·0		Film 412 (a), Focus 7·0		...	...	...	...
000	4143·581	...	...	...	...	...	...
·000	**4144·033**	000	**4144·033**	...	...	...	...
− ·005	4147·841	...	...	...	...	...	...
15	4154·117	...	...	...	...	...	...
16	4154·662	+ ·005	4154·662	− ·001	4154·662	...	...
19	4156·974	5	4156·954	4	4156·949	...	...
41	4175·797	3	4175·801	13	4175·802	...	...
45	4179·582	...	...	...	...	...	...
47	4181·926	6	4181·917	5	4181·918	...	...
...	...	13	4183·591	− ·002	4183·600	...	...
50	4185·057	21	4185·063	...	...	...	...
51	4187.210	25	4187·221	+ ·001	4187·219	...	...
52	4187·967	26	4187·975	1	4187·976	...	...
53	4190·008	...	...	...	...	...	...
54	4191·625	28	4191·611	2	*4191·534	...	...
57	4198·461	25	4198·472	...	...	...	...
57	4199·255	24	4199·266	0	4199·256	...	...
57	4202·184	22	4202·193	000	**4202·195**	...	...
...	...	...	...	Film 265 (a), Focus 6·5		Film 265 (a), Focus 7·5	
...	...	...	...	− ·002	4198·463	...	...
...	...	...	...	− ·001	4199·252	·003	4199·258
...	...		...	000	**4202·195**	000	**4202·195**
...	...		...	+ ·003	4205·245	...	...
58	4210·512	15	4210·525	...	...	...	...
57	4216·340	...	...	...			...
56	4219·528	10	4210·525	14	4219·528	...	...
55	*4222·477	8	4222·381	16	4222·372	...	...
54	4224·306	...	...	...	...	...	
53	4226·866	...	...	...	...		...
54	4224·306	...	...	...	...	...	...
53	4226·866	...	...	...	...	...	...
52	4227·589	6	4227·597	19	4227·606	− ·066	4227·654
49	4232·620	5	4232·621	...	...	...	...
49	4233·101	...	...	...		...	...
48	4233·763	5	4233·778	22	4233·785	...	...
48	4234·162	...	...	...	...	...	...
47	4236·084	4	4236·119	23	4236·121	78	4236·105
45	4238·975	...	...	...	...	...	...
39	4247·587	...	...	27	4247·535	...	...
37	4250·309	5	*4250·020	...	...	87	4250·294
37	4250·954	5	4250·947	28	4250·956	87	4250·970
31	4260·673	4	4260·657	30	4260·649	88	4260·668
28	4268·801	3	4268·805	31	4268·822	86	4268·819
27	4271·325	3	4271·334	32	4271·343	86	4271·333
...	...	3	4271·721	...	...	...	...
27	4271·908	3	4271·930	33	4271·927	86	4271·911
...	...	3	4271·975	...	...	...	...
25	4277·125	3	4277·119	34	4277·109	...	...
23	4282·571	2	4282·567	37	4282·579	83	4282·576
22	4284·226	2	4284·218	38	4284·203	...	...
19	4291·987	1	4291·990	43	4291·968	...	...
19	4294·322	1	4294·301	44	4294·299	75	4294·288
18	4296·264	1	4296·281	...	...	...	...
17	4297·841	...	...	...	...		...
17	4298·202	...	...	...	...	...	...
17	4299·418	+ ·000	4299·420	46	4299·409	69	4299·419
14	4306·388	...	...	...	...	...	...
14	4307·349		...	...	...	...	...
− ·013	4308·086	000	**4308·081**	+ ·048	4308·081	− ·061	4308·068
...		Film 412 (a), Focus 7·0		...	...	...	...
...	...	000	**4308·081**	...	...	...	...

Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.
—·013	4309·966	...	...	...	...	...	...
10	4315·258	—·002	4315·265	+·050	4315·265	—·055	4315·243
5	4325·961	6	4325·934	51	4325·931	48	4325·948
3	4330·168	7	4330·194	51	4330·194	...	...
—·002	4332·995′	7	4332·998	51	4332·995	44	4332·990
·000	**4337·219**	8	4337·499*	51	4337·236	...	...
+·001	4341·182	8	4341·171	50	4341·173	40	4341·174
+·004	4353·023	8	4353·008	47	4353·034	35	4353·028
Film 401, Focus 7·0		...	...	...	...	...	...
·000	**4337·219**	...	...	...	...	...	...
—·000	4341·181	...	...	...	...	...	...
1	4353·033	...	...	...	...	...	...
3	4376·095	...	...	...	...	...	...
4	4378·861	...	...	...	...	...	...
...	...	8	4379·426	33	4379·387	22	4379·412
4	4383·720	8	4383·728	29	4383·702	19	4383·725
5	4384·905	8	4384·895	28	4384·874	18	4384·882
5	4390·177	8	4390·155	22	4390·136	14	4390·152
6	4395·428	8	4395·666*	16	4395·392	9	4395·404
6	4400·735	8	4400·725	10	4400·752	—·004	4400·753
7	4404·937	8	4404·946	6	4404·938	·000	**4404·929**
7	4406·813	8	4406·805	5	4406·834	Film 265 (*a*), Focus 7·5	
...	...	...	...	...	...	·000	**4383·724**
...	...	...	...	...	...	—·000	4384·886
...	...	...	...	...	...	1	4390·168
...	...	...	...	...	...	3	4395·411
...	...	...	...	...	...	4	4400·757
...	...	...	...	...	...	4	4404·922
...	...	...	...	...	...	5	4406·818
8	4407·798	8	4407·804	4	4407·825	5	4407·815
8	4408·334	8	4408·335	3	4408·380	...	...
8	4408·744	8	4408·716	+·003	4408·694	...	...
8	4412·326	...	...	...	...	...	...
8	4415·319	10	**4415·291**	·000	**4415·301**	6	4415·306
8	4416·636	10	4416·730*	...	...	6	4416·648
8	4420·106	12	4421·751	...	...	5	4421·775
8	4426·174	14	4426·199	...	...	...	...
8	4427·473	15	4427·490	...	...	...	...
8	4428·676	16	4428·694	...	...	...	...
8	4429·965	...	...	...	...	...	...
7	4436·300	22	4436·312	...	...	3	4436·323
7	4437·706*	...	...	...	...	...	...
...	...	24	4438·007	...	...	3	4438·028
6	4441·842	28	4441·848	...	...	3	4441·886
6	4442·505	...	...	...	...	...	...
6	4444·371	31	4444·369	...	...	3	4444·407
5	4447·896	...	...	...	...	...	...
4	4452·173	40	4452·176	...	...	2	4452·204
1	4459·287	...	...	...	...	...	...
1	4459·923	50	4459·922	...	...	1	4459·956
1	4460·493	51	4460·455	...	...	1	4460·518
—·000	4462·534	53	4462·524	...	...	·001	4462·576
...	...	...	...	Film 323, Focus 7·0		...	...
+·001	4466·730	58	4466·733	·000	**4466·737**	·000	**4466·737**
3	4469·879	...	...	—·021	4468·192	...	...
...	...	...	...	38	4468·962	...	...
3	4469·879	63	4469·888	50	4469·882	+·000	4469·919
4	4474·221	...	...	·100	4474·228	...	...
4	4474·902	69	4474·914	105	4474·899	...	...
4	4476·209	71	4476·215	·120	4476·206	...	...
...	...	...	...	·140	4480·235	...	...
5	4482·401	79	4482·434	·151	4482·435	...	...
...	...	...	...	·159	4484·420	...	...
5	4489·077	·088	4489·150	180	4489·101	...	...
...	...	Film 407, Focus 7·0		·191	4490·996	...	...
—·004	4494·725	·000	**4494·755**	—·201	4494·756	...	...

Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.
...	...	...	...	—·206	4496·237	...	...
...	...	...		·208	4497·055	...	...
+·003	4502·147	+·005	4502·160	·216	4502·146	...	...
+·001	4524·463	17	4524·413	231	4524·381	...	...
...	...	17	4525·368	·231	4525·322	...	...
·000	**4528·798**	19	4528·809	·226	4528·776	...	...
...	...	19	4531·366	·222	4531·341	...	...
·001	4545·583	19	4549·[illegible]7	·186	4549·797	...	...
...	...	18	4553·251	178	4553·254	...	...
...	...	...	...	171	4556·847	...	...
2	4560·9[illegible]6	17	45[illegible]0·897	159	4560·919	...	...
...	...	...	...	150	4564·788	...	...
2	4571·980	15	4571·972	...	...	...	...
2	4577·370	13	457[illegible]·359	·123	4577·390	...	...
2	4578·930	13	4578·907	120	4578·921	...	...
3	4580·599	13	4580·564	116	4581·596	...	...
...	...	...	...	122	4584·005	...	...
3	458[illegible]·553	11	4586·540	·119	4586·548	...	...
3	4591·422	10	4591·413	·104	4591·400	...	...
−·003	4594·274	9	4594·277	·101	4594·287	...	...
...	...	...	...	95	4600·287	...	...
...	...	6	46[illegible]3·12	93	4603·130	...	...
...	...	6	4606·326	90	4606·324	...	...
...	...	5	4619·8[illegible]4	78	4619·865	...	...
...	...	4	4635·345	64	4635·332	...	...
...	...	4	4646·558	53	4646·542	...	...
...	...	...	...	34	4666·204	...	...
...	...	3	4670·649	30	4670·595	...	...
...	...	...	...	23	4677·729	...	...
...	...	...	...	16	4688·049	...	...
...	...	+·001	4706·471	—·000	4706·659	...	...
...	...	·000	**4736·963**	·000	**4707·457**	...	...
...	...	Film 407, Focus 7·0		Film 323, Focus 7·0		...	...
...	...	...	...	·000	**4707·457**	...	...
...	...	...	...	+·007	4710·648	...	...
...	...	·000	**4736·963**	44	4736·943	...	...
...	...	+·003	4775·260	42	4775·276	...	...
...	...	3	4776·125	42	4776·134	...	...
...	...	4	4778·239	41	4778·256	...	...
...	...	4	4781·441*	40	4781·515*	...	...
...	...	4	4783·195	39	4782·917*	...	...
...	...	5	4797·101	33	4796·826*	...	...
...	...	5	4807·695	28	4807·701	...	...
...	...	...	...	22	4820·150*	...	...
...	...	6	4821·220	22	4820·954*	...	...
...	...	...	...	21	4822·306*	...	...
...	...	...	...	...	4825·824*	...	...
...	...	6	4827·616	20	4827·613	...	...
...	...	7	4831·811	18	4837·806	...	...
...	...	7	4832·586	18	4832·590	...	...
...	...	7	4833·249	17	4833·260	...	...
...	...	7	4838·837	16	4838·852	...	...
...	...	7	4841·808	15	4841·804	...	...
...	...	8	4851·632	12	4851·651	...	...
...	...	8	4856·969	10	4856·965	...	...
...	...	...	...	9	4859·925	...	...
...	...	7	4864·895	8	4864·888	...	...
...	...	7	4871·507	6	4871·495	...	...
...	...	6	4872·344	6	4872·352	...	...
...	...	6	4875·646	5	4875·655	...	...
...	...	...	...	5	4876·320	...	...
...	...	...	...	4	4877·963	...	...
...	...	5	4881·732	3	4881·720	...	...
...	...	...	...	3	4882·337	...	...
...	...	+·001	4890·938	+·001	4890·948	...	...
...	...	·000	**4891·683**	·000	**4891·683**	...	...
...	...	...	...	—·002	4899·065	...	...
...	...	·002	4901·663	2	4901·733	...	...
...	...	...	...	−·003	4904·627	...	...

SESSIONAL PAPER No. 25a

Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.	Correction.	Corrected Wave-Length.
....	....	− ·003	4906·898	·003	4906·872	....	....
...	...	4	4911·148	4	4911·125	....	....
....	....	....	....	4	4912·140	....	....
....	....	− ·005	4914·418	—·005	4914·319	....	....

* Omitted in calculating the mean.

SUMMARY.

Mean of Corrected Wave-Lengths.	Intensity.	Width in Mm.	Remarks.	Rowland and Harrison Vânadium.	Rowland Solar. Vanadium.	Rowland Solar. Iron.	Kayser Iron.
3895·801						3895·803	3895·801
3898·100				3898·082	3898·151	3898·032 3898·231	
3899·283						3899·171	
3899·853						3899·850	3899·853
3902·408				3902·371	3902·399		
3903·097						3903·090	3903·097
3903·412						3903·398*u*	
3906·588						3906·628	3906·624
3910·028						3909·976	3909·980
3914·469				3914·437		3914·426Fe,?	
3916·574						3916·544*u* 3916·879	3916·880
3920·406	7	10	Weak line to red.			3920·410	3920·404
3923·057	8	·10				3923·054	3923·059
3928·075	8	11	Weak edges.			3928·075	3928·073
3930·446	7	·10				3930·450	
3933·815				3933·775			
3934·151	1	07				3934·174*u*	
3948·920	2	·06				3948·925	3948·927
3950·101	1	·06				3950·102	
3952·103	5	·08		3952·073			
3956·642	1	·08	Hazy edges.			3956·603	3956·610
3956·836	2	·07				3956·819	3956·823
3966·754	1	·07				3966·778	3966·219
3967·675	1	05				3967·570	
3968·237	1	06				3968·114	
3968·634				3968·588		3968·625Ca	
3669·412	11	12				3969·313	3969·411
3973·790	3	·06				3973·796	
3977·896	2	06				3977·891	3977·892
3984·123	1	06				3984·113	3984·112
3990·723	5	·07		3990·693	3990·712		
3992·954	3	·07		3992·916	3992·971V-Cr		
3997·275	1	·07			3997·115		
3997·559	2	·05			3997·547		
3998·881	3	07		3998·847	3998·790Ti	3998·205	
4003·159							
4005·429	8	10					
4005·867	5	09		4005·838		4005·468	
4009·885	1	05				4009·864	
4014·697	1	05				4014·677	
4022·044	2	06		4022·038		4022·018	4022·029
4023·555	5	·08	Weak to violet.	4023·508			
4035·793	5	08					
4043·293	1	06					
4045·980	12	19	Weak edges.			4045·975	4045·978
4051·130	1	07			4051·204		
4051·499	1	07		4051·485	4051·491Cr-V		
4057·244	1	·05		4057·206			
4061·069	1	05				4061·081*u*	
4062·626	1	05				4062·599	4062·605
4063·756	11	18	Weak edges, line to red.			4063·759	4063·755
4065·229					4065·239Mn-Ti		
4071·904	12	18		4071·664		4071·908	4071·901
4090·728	7	08		4090·703	4090·728		
4092·849	6	·09	Weak line to violet	4092·532!	4092·821	4092·431 4092·665	
4095·938	8	10		4199·921!	4099·941		
4102·306	3	·06		4102·285	4102·321		
4105·313	6	09			4105·318		
4107·643	1	05		4107·599		4107·649Ca-Fe-Zr.	4107·646
4109·918	7	·10		4109·906	4109·905	4109·953	
4111·937	7	·19	Weak edges.	4111·916	4111·940		

SUMMARY—*Continued.*

Mean of Corrected Wave-Lengths.	Intensity.	Width in Mm.	Remarks.	Rowland and Harrison Vanadium.	Rowland Solar. Vanadium.	Rowland Solar. Iron.	Kayser Iron.
4115·322	6	12	Weak edges	4115·311	4115·330		
4116·646	5	09		4116·631	4116·634		
4118·710	4	07		4118·320	4118·307	4118·708	4118·709
4123·651	5	·09			4123·589	4123·907	
4128·214	6	·09		4128·152!	4128·251		
4132·174	8	·13		4132·123	4132·100	4134·233Fe-V	
4134·613	6	·08		4134·617	4134·509Fe-V		
4134·626	6	·16	Resultant				
4134·860	1	·04				4134·840	
4143·585	2	·06				4143·572	
4144·033	7	·11				4144·038	4144·033
4147·841						4147·836	
4154·117						4154·071	
4154·662	1	·06				4154·667	4154·662
4156·959	1	05				4156·970	
4175·800	1	·05				4175·806	4175·799
4179·582					4179·542		
4181·920	6	·06				4181·919	4181·918
4183·596	1	·06		4183·071			
4185·060	1	·05				4185·058	
4187·217	5	·08				4187·204	4187·221
4187·973	5	·08				4187·943	
4190·008				4190·011	4189·983		
4191·618	3	·07	Hazy to red			4191·595 4191·843	4191·611
4198·465	5	·07				4198·494	
4199·257	7	·08				4199·267Zr-Fe	4199·256
4202·192	8	·10	Faint line to red.	4202·506		4202·198	4202·195
4204·130						4204·101	
4205·245				4205·201		4205·545	
4210·006				4210·002	4209·985		
4210·519	1	·06				4210·494	4210·521
4216·340						4216·351	
4219·527	3	·06				4219·516	4219·523
4222·377	1	·05				4222·382	4222·387
4224·306						4224·337	
4226·866				4226·871			
4227·612	6	·07	Weak line to red.			4227·606	4227·606
4232·621	1	·06		4232·604	4232·618*u* 4232·767		
4233·101			Hazy to red	4233·007	4233·086		
4233·775	3	·06				4233·772	4233·771
4234·162				4234·149	4234·171Co-V		
4236·107	5	·08	Weak line to violet	4235·909		4236·112	4236·118
4238·975			Weak edges			4238·970	4238·980
4247·561			"			4247·591	4247·604
4250·302	6	·06				4250·287	4250·299
4250·957	7	10				4250·945	4250·948
4260·662	7	·12	Hazy edges			4260·640	4260·656
4268·812	5	·08	Weak line to red.	4268·787		4268·915	
4271·333	5	·08				4271·325	4271·333
4271·721	3	·06		4271·706			
4271·919	7	·19	Resultant				
4271·975	8	12				4271·934	4271·933
4277·118	3	·06		4277·101	4277·147V-		
4282·573	4	·06				4282·565	4282·567
4284·216	2	·06				4282·565	4282·567
4291·982	1	·05		4291·978			
4294·303	5	·08				4294·301	4294·290
4296·273	1	·04		4296·266			
4299·417	5	·08	Hazy edges	4299·240		4299·410Ti-Fe	4299·420
4306·388							
4307·349						4307·342*u*	
4308·080	12	·18				4308·081	
4309·966				4309·949			
4315·258	2	·06				4315·262	4315·255

SUMMARY—*Continued.*

Mean of Corrected Wave-Lengths	Intensity.	Width in Mm.	Remarks.	Rowland and Harrison Vanadium.	Rowland Solar. Vanadium.	Rowland Solar. Iron.	Kayser Iron.
4325·941	12	·18				4325·939	4325·941
4330·185	2	06		4330·181	4330·189		
4332·995	3	07		4332·985	4332·988		
4337·225	1	05				4337·216	4337·218
4341·176	5	07		4341·162	4341·167		
4353·025	5	·10	Close double..... Weak line to violet	4253·040	4353·044	4352·908	4352·910
4367·941!							4367·759
4376·095						4376·107	4376·104
4378·861							
4379·409	12	19		4379·392	4379·396		
4383·720	9	19	Weak edges....			4383·720	4383·724
4384·888	9	16	Weak edges to red	4384·875	4384·873		
4390·158	10	16	Weak edge to red	4390·142	4390·149		
4395·407	9	11	Weak to red.	4395·382	4395·413		
4400·744	8	·10		4400·738	4400·738		
4404·935	9	·15	Weak edges			4404·927	4404·929
4406·818	8	·10		4406·805	4406·810		
4407·811	9	·11		4407·801	4407·810	4407·871	
4408·350	7	09		4408·368	4408·364		
4408·719	7	17		4408·665	4408·633	4408·582	
4412·326				4412·299	4412·297		
4415·301	8	·10				4415·293	4415·301
4416·646	2	07		4416·626	4416·636		
4420·106					4420·100		
4421·756	2	·07	Weak edge to red.	4421·739	4421·733		
4426·184	1	·06	Weak line to violet	4425·594	4426·201Ti		
4427·482	1	05				4427·482	4427·490
4428·685	1	06		4428·676	4428·711V–Cr		
4429·965					4429·958		
4436·312	2	08		4436·309	4436·313		
4438·018	4	08		4438·004	4438·006		
4441·859	4	·09		4441·847	4441·881V—		
4442·505						4442·510	4442·522
4444·382	4	·08		4444·380	4444·385*u*		
4447·896						4447·892	4447·907
4452·184	5	10		4452·180	4452·171		
4457·642	1	07	Weak edge to red.	4457·632	4457·600Ti–V Zr......		
4459·287						4459·301	
4459·934	3	·09		4459·918	4459·922		
4460·489	4	·12	Hazy edge to red.	4460·462	4460·462		
4462·543	3	·09		4462·533	4462·525		
4466·734	2	07				4466·727	4466·737
4468·192				4468·174	4468·160*u*		
4468·962				4468·931	4468·914*u*		
4469·890	3	07	Hazy to violet...	4469·871	4469·873		
4474·225				4474·207	4474·213*u*		
4474·905	2	06	Hazy edges. ..	4474·899	4474·912*u*		
4476·210	2	07				4476·185	4476·207
4480·235				4480·206	4480·308		
4482·423	1	07				4482·438	
4484·420						4484·392	4484·420
4489·109	5	09		4489·096	4488·928!	4489·075!	
4490·996				4490·981	4490·975*u*	4490·942	
4494·745	3	09				4494·738	4494·755
4496·237				4496·233			
4497·055				4497·574	4497·023Cr		
4502·151	1	06	Hazy	4502·121	4502·157*u*		
4514·383				4514·357		4514·358Fe, Co	
4524·399	2	08		4524·378	4524·378*u*		
4525·344	1	08		4525·337		4525·314	
4528·794	5	13	Hazy edges.	4528·168		4528·798	
4531·350	2	07				4531·327	
4545·588	5	10		4545·566	4545·507Cr–V	4545·568u	
4548·038						4548·024	

SUMMARY—*Concluded.*

Mean of Corrected Wave Lengths	Intensity.	Width in Mm.	Remarks.	Rowland and Harrison Vanadium.	Rowland Solar. Vanadium.	Rowland Solar. Iron.	Kayser Iron.
4549·818	1	·09	Hazy to violet....	4549·824	4549·808Ti-Co	4549·642	
4553·253	1	·06					
4556·847							
4560·907	4	·10		4560·893	4560·892*u*		
4564·788				4564·756	4564·750*u*		
4571·976	3	·09		4571·959	4571·976*u*		
4577·373	6	·11		4577·348	4577·356		
4578·919	1	·08		4578·908	4578·909		
4580·588	7	·13		4580·562	4580·590		
4504·005						4584·018	
4586·547	8	13		4586·554	4586·552		
4591·412	1	·08	Hazy to violet...	4591·406	4591·421*u*		
4594·279	9	16		4594·216	4594·297		
4600·363							
4603·128	1	·06				4603·126	
4606·325	1	·07		4606·321			
4619·870	3	·10		4619·896	4619·852*u*		
4635·339	1	·05		4635·346	4635·352		
4646·550	1	·06		4646·571	4646·552*u*		
4666·204							
4670·622	2	·07		4670·666	4670·590*u*		
4706·565!	1	·07		4706·357			
4707·457				4707·629		4707·457	
4710·648				4710·746	4710·737*u*	4710·471	
4736·943	1	·07				4736·963	
4775·268	3	·10					
4776·130	4	·10					
4781·558!	2	·07		4781·514			
4783·195!	2	·08			4783·169*u*		
4786·165	3	·10		4786·706		4786·145*u*	
4797·101!	3	·09		4797·119			
4807·698	2	·07		4807·736		4807·900	
4827·615	2	·09	Hazy............	4827·638	4827·637		
4831·809	2	·08		4831·8[illegible]6	4831·831		
4832·588	1	·08		4832·617	4832·615		
4833·255	1	·10		4833·213			
4838·845	3	·10				4838·837 Fe-Ni—Si.?	
4841·806	1	·10					
4851·642	5	·09		4851·686	4851·689 Cr--V		
4859·925						4859·928	
4864·892	5	·10		4864·943	4864·919		
4871·501	7	·11		4871·453	4871·512		
4872·348	1	·07	Hazy..			4872·332	
4875·651	7	·10		4875·674	4875·671		
4876·320							
4877·963							
4881·726	7	·11		4881·745	4881·739		
4882·337				4882·359	4882·336		
4890·943	1	·10		4890·265	4890·948		
4891·683	6	·10		4891·414 4891·767		4891·683	
4899·065							
4901·698	8	10					
4904·627				4904·575	4904·597*u*		
4906·885	8	·10			4906·885		

u. Unidentified in Rowland's Solar Table. In most cases it will be observed these unidentified lines correspond closely to the Vanadium lines of Rowland and Harrisons' Tables.

APPENDIX E.

PHOTOMETRIC OBSERVATIONS.

W. M. Tobey.

Photometric observations are now being made at the Dominion Observatory with a new Polarizing Photometer. This method started in September of last year. Previous to that time the wedge photometer was mainly used. By that method the image of a star was intercepted by a wedge of coloured glass and finally extinguished by movement of the wedge. Thus comparisons were made by recording 'the extinguishing points' of the star's light. This offered many difficulties to the observer, on account of the diffusion of the image at that stage, the uneven absorption of the wedge, and the fact that such observations are very trying to the eyes on account of the straining to keep in sight an object just as it is becoming invisible.

To obviate these difficulties and not to make all comparisons at the critical point of the extinguishing of the star's light, resort was made to our polarizing photometer. Its essential principle is that comparisons are made with a standard artificial star, whose light is first passed through a double image prism. By rotation of an analyser, the light of the artificial star is made to be of the same intensity as that of the real star. Hence if two different stars are compared in succession with the artificial star and if θ and θ_1 are the respective angles of rotation of the prism from the position in which the light is extinguished, we have

$\frac{I}{I_1} = \log\left(\frac{\sin^2\theta}{\sin^2\theta_1}\right)$ where I and I_1 are the intensities of our two stars.

Thus the intensity of one star can be found when the other is previously known. Dividing the above ratio by ·4 the logarithm of 2·512, one obtains the difference of magnitude.

The operation of this photometer being purely 'differential,' differences of magnitudes alone being observed, stars only of nearly same zenith distances are to be compared. Thus no correction for distance of a star from the zenith is necessary as in other photometers, where comparisons are generally made with Polaris directly.

The vicinity of S. Cassiopeiæ, being a field that is well determined photometrically, was used for testing. Here there are a number of stars, differing in magnitude, but situated at very nearly the same zenith distance. Thus were used:—

Star.	R. A. h. m. s.	Dec.
b	1 11 25	71° 52′·9
c	1 11 15	72° 20′·8
d	0 44 16	73° 00′·5
e	1 23 14	72° 21′·6
f	1 24 30	72° 23′·6

Which were paired as follows:—

	Reading of Graduated Circle.	Angle from Extinction.	Log $\sin^2\theta$.	Log $\frac{\sin^2\theta}{\sin^2\theta_1}$	Difference of Magnitude.
c	123, 268·5, 305, 88	17·9	8·9752	....	....
b	85, 127, 270, 309·5	20·3	9·0804	·1052	·26
b	302, 89, 124,269	17·0	8·9318	....	....
c	272, 302, 89·2,118	14·7	8·8088	·1230	·31
b	270·2,301·5, 88·7,119	15·4	8·8484	....	....
c	115,272, 300·9,90	13·5	8·7364	·1120	·28
c	91,115, 298,273	12·2	8·6500	....	....
b	272,299·2, 89·1,119	14·2	8·7794	·1294	·32
c	296·5,271, 90,116	12·7	8·6842	....	....
d	112,92·7, 292,274	9·3	8·4170	·2672	·67
c	114, 91, 271,297	12·2	8·6500	....	....
d	293, 274, 111·2, 93	9·3	8·4170	·2330	·58
c	118, 89, 299, 273·5	13·6	8·7426	....	....
f	273·8, 294·7, 90, 115·2	11·5	8·5994	·1432	·36
f	111, 93, 273·5, 292	9·1	8·3980	....	....
c	294 272, 90, 113	11·2	8·5766	·1786	·45

Which may be summarized:—

Star (Compared).	Determined Difference of Magnitude.	Residual.	Harvard Value.
b and *c*	·26	—03	
	·31	—02	
	·28	—01	
	·32	03	
	Mean ·29		·27
c and *d*	·67	05	
	·58	—04	
	Mean ·62		·45
c and *f*	·36	—04	
	·45	05	
	Mean ·40		·33

OBSERVATIONS IN VICINITY OF NORTH POLE.

Star.	Reading of Circle.	θ	L. $\sin^2\theta$	Log $\frac{\sin^2\theta}{\sin^2\theta_1}$	Difference of Magnitude.	V.
a	81, 135, 261, 321	28·°	9·34320	....	....	....
b	300·2, 84, 121, 270	15·5	8·85380	·48942	1·23	—19
b	270, 300, 89, 117	14·5	8·79720	....	....	....
a	143, 328, 78, 258	33·7	9·48834	·69114	1·73	·31
a	147, 259, 327, 76	34·7	9·51066	....	....	....
b	85, 125, 270, 306	19·0	9·04528	·48538	1·21	—21
a	330·5, 150, 76, 257	37·6	9·57120	....	....	....
b	273, 121, 905, 315·5	18·4	8·99840	·57280	1·43	01
b	272, 127, 89·9, 315·2	20·0	9·06810	....	....	....
a	334, 73, 152, 257	39·0	9·59474	·52964	1·32	-10
a	256, 330, 75·5, 149	36·9	9·5770	....	....	....
b	121, 89·3, 303, 269	16·4	8·9016	·6554	1·62	·20
				Mean	1·42	

Which is somewhat less than that (1·54) given in Harvard Annals 48.

OBSERVATIONS IN FIELD OF U ORIONIS.

Star.	Reading of Circle.	θ	Log $\sin^2\theta$	Log $\frac{\sin^2\theta}{\sin^2\theta_1}$	Difference of Magnitude.	V.
a	151, 73, 258, 334	38·5	9·5882	....	....	....
b	327, 260, 77, 141	32·4	9·4572	·1320	·33	·30
f	300, 272, 90, 118	14·0	8·7674	....	....	....
g	293, 270, 93, 112	12·0	8·6358	·1316	·33	·42
h	331, 252, 71, 153	40·	9·6162	....	....	....
k	142, 81, 259, 328	32·5	9·4604	·1558	·39	33
k	259, 329, 145, 79	34·	9·4952	....	....	....
l	263, 323, 82, 141	30·	9·3980	·0972	·24	33

OBSERVATIONS OF *W Ursae Majoris.*

This is a short period variable.

Star.	Circle Reading.	θ	Time.	Log $\sin^2\theta$	Log $\frac{\sin^2\theta}{\sin^2\theta_1}$	Difference of Magnitude.
Var	314, 266, 85, 136	25·7	1·00 A.M.	9·2742		
A	126, 90, 270, 302	17·0	1·03 "	8·9318	·3424	·86
A	301, 273, 122, 90	15·0	1·15 "	8·8260		
Var	85, 129, 267, 312	23·7	1·20 "	9·2084	3824	·95
Var	310, 270, 87, 128	20·7	1·37 "	9·0968		
A	120, 89, 303, 271	15·7	1·40 "	8·8646	·2322	·58
A	273, 296, 89, 118	13·5	1·55 "	8·7364		
Var	132, 86, 268, 320	24·5	1·57 "	9·2354	·4990	1·25
Var	314, 266, 84, 136	25·0	2·17 "	9·2518		
A	118, 89, 270, 303	15·0	2·20 "	8·8260	·4258	1·06
A	301, 271, 90, 120	15·0	2·37 "	8·8260		
Var	132, 84, 266, 315	24·7	2·42 "	9·2420	4160	1·04
Var	315, 267, 83, 135	25·0	3·00 "	9·2518		
A	122, 90, 271, 303	16·0	3·03 "	8·8806	·3712	·93
A	305, 270, 90, 118	16·7	3·17 "	8·9168		
Var	137, 81, 262, 317	27·5	3·22 "	9·3288	·4120	1·03
Var	314, 265, 83, 137	25·7	3·57 "	9·2742	5352	1·34
A	118, 90, 272, 299	13·7	4·00 "	8·7490		
A	297, 271, 115, 90	12·7	4·17 "	8·6842		
Var	137, 82, 265, 318	27·0	4·20 "	9·3140	·6298	1·57
Var	313, 268, 84, 127	22·0	4·40 "	9·1472		
A	118, 89, 270, 298	14·2	4·43 "	8·7794	·3678	·92
A	302, 270, 90, 118	15·0	4·58 "	8·8260		
Var	124, 87, 268, 305	18·2	5·02 "	9·0030	·1770	·45
Var	308, 268, 87, 125	19·7	5·10 "	9·0556		
A	117, 91, 273, 301	13·5	5·12 "	8·7362	·3194	·80

Thus approximate minima were shown at $1^h\ 36^m$ and 5^h, while at 2^h it had regained its fullness of magnitude and held it till $4^h\ 25^m$, when a decline set in. Other observations are, of course, necessary here to complete and refine the determination of the period, &c.

A word might be said in reference to some of the peculiarities and difficulties attached to photometric observations, difficulties to which the observer is almost constantly exposed. Probably the greatest is that due to difference of colour of the two stars to be compared, for it is seldom that two stars are alike in that respect. The great majority of stars are bluish or almost white like Sirius. Against this class we have those of a yellow tint like Capella, those of a red colour like Arcturus, and some even of a deeper red hue. To compare one star of a bright green or blue colour with another which may be anywhere in the scale from that colour to deep red, offers the very greatest embarrassment, because it is impossible to make a red star identical with a blue by any mere increasing or diminishing of its brightness, and because no two observers will agree in making the measurement for comparisons, as some eyes may be peculiarly sensitive to blue light and others to red light. The experience of the writer has shown that this is even intensified, when the difference of magnitude between the two stars is increased, for the greater that difference the greater the intensity of the respective colours. And it therefore seems, that to reduce the colour effect as much as possible, it is well to use stars differing not too much in magnitude, say not greater than one-half a magnitude. In case the difference of magnitude is greater, it is well to use stars of an intermediate magnitude and so arrive at the final comparison, though such intermediate stars are not always to be obtained, especially those whose magnitudes are known with accuracy.

And then it is absolutely essential that the sky should be free from clouds and of a uniform transparency. As Parkhurst, in Researches in Stellar Photometry, says: 'A patchy sky' is the signal to stop work. For this reason many nights, which to an

observer in other lines, would prove to be good for accurate work, must be discarded on account of presence of sheets of haze or otherwise undesirable and fluffy sky. Many is the night, with its observations which have been lost in that way.

Temperature is also an important factor to be reckoned with. At low temperatures the proximity of the eye alone is sufficient to dim with frost the eye-piece, and as this dimming does not necessarily take place evenly over the surface, but rather unevenly, observations as such cannot be relied upon. Thus the eye-piece may be partly dimmed so as to affect the real star, and not affect the artificial one at all or to the same degree.

To attain good results it is also necessary to pay strict attention to some other facts, one of which is that the star to be compared and the artificial one should always be in a constant position, i.e., they should not be sometimes in a vertical, slanting or horizontal line, but always in one same position. The horizontal position seems to be the best and it is the experience of the writer that unless this is done, serious differences in the estimation of the brightness will ensue.

The work on long period variables, stars whose period may be as much as a year or a year and a half, will not be affected by the above difficulties to the same extent, for on any one night, that is favourable, a number of measurements can be taken and the mean value used, so as to eliminate those effects. But not so with some of our irregular and short period variables, some of only a few hours duration, and which necessarily demand observations of almost a continuous nature, especially near the minama where the changes are sudden. With these the most perfect of weather conditions, &c., are to be desired, so that each measurement can be taken as a standard one.

Classified, the work is to determine the photometric magnitude of all such standard stars as are necessary for the determination of variables and the determination, both in amount and period of duration, of the light variation of these different variables by observations. These observations, for long period variables, must necessarily be extended over a considerable lapse of time, while for irregular and short period variables they should be as continuous and frequent as is possible. It then becomes necessary to determine all those interesting variables of the type 'Algol,' a star whose light is periodically eclipsed by some dark revolving body and whose variation is, therefore, determined by photometric means; to determine the type of our long period variable whether of *o* Ceti or *U* Geminorum type; to determine the nature of our short period variables, whether of type δ Cephei or β Lyrae, and lastly, those whose variations are of an irregular nature.

In conclusion, I wish to express my thanks for the very kind assistance and suggestions given to me by Mr. J. S. Plaskett.

APPENDIX 3

REPORT OF THE CHIEF ASTRONOMER, 1908

MERIDIAN WORK AND TIME SERVICE

By R. M. STEWART, M.A.

CONTENTS.

ILLUSTRATIONS.

APPENDIX 3.

REPORT OF R. M. STEWART, M.A., ON MERIDIAN WORK AND TIME SERVICE

OTTAWA, March 31, 1908.

W. F. KING, Esq., B.A., LL.D.,
Chief Astronomer,
Department of the Interior,
Ottawa.

SIR,—I have the honour to report as follows on the work carried out under my charge during the past year.

As in previous years, the time service at the Observatory and the Government Buildings in the city has been kept in operation, and extensions and improvements made. The system of synchronized clocks has been extended to the Post Office, including a six-foot tower clock which is operated electrically, and which has an automatic attachment to control its own illumination. The clocks and electrical apparatus for the Printing Bureau, the Mint and the Archives have been on hand for some time, and everything is in readiness to extend the system to these buildings also, as soon as the necessary wiring shall have been completed by the Department of Public Works. A system of automatic cut-outs has been installed in the various master-clocks, by which, in case of their getting out of step on account of any derangement of the synchronization line, they will cut themselves out of synchronization, and so obviate any danger of stoppage on that score. The usual amount of observing has been done for longitude, clock error, rating of chronometers, &c.

The investigation into the errors of observation with portable transit instruments was continued and a satisfactory conclusion arrived at, so far as concerns the class of errors considered. The information gained in the inquiry will be applied to the observations in the field in the coming summer, with a view to which some necessary alterations have already been made in the micrometers of the field transits. A travelling-wire micrometer for Cooke Transit No. 1 was made in the workshop during the summer of 1907; it was modelled for the most part on those already in use on Transits Nos. 2 and 3, but contained such modifications as experience had suggested; a more detailed description is given below.

The meridian circle arrived about the end of October, and was mounted a short time later. Some transit observations were made under difficulties in the early part of the winter, but, owing probably to an accident in shipment, no use could be made of the vertical circles, which were accordingly returned to the makers for repairs. Later it developed that the piers on which the instrument was mounted were unstable, which will, unfortunately, necessitate their complete reconstruction. Work on the opening mechanism for the roof shutters, and the reconstruction of the vertical wall-shutters, is in progress, but it will probably be some months before the instrument can be got ready for service.

I wish to acknowledge my indebtedness to Mr. D. B. Nugent for assistance in preparing the tables for this report, and to Mr. C. C. Smith for preparing the drawings and for considerable assistance in checking the computations.

SECTION I.

TIME SERVICE.

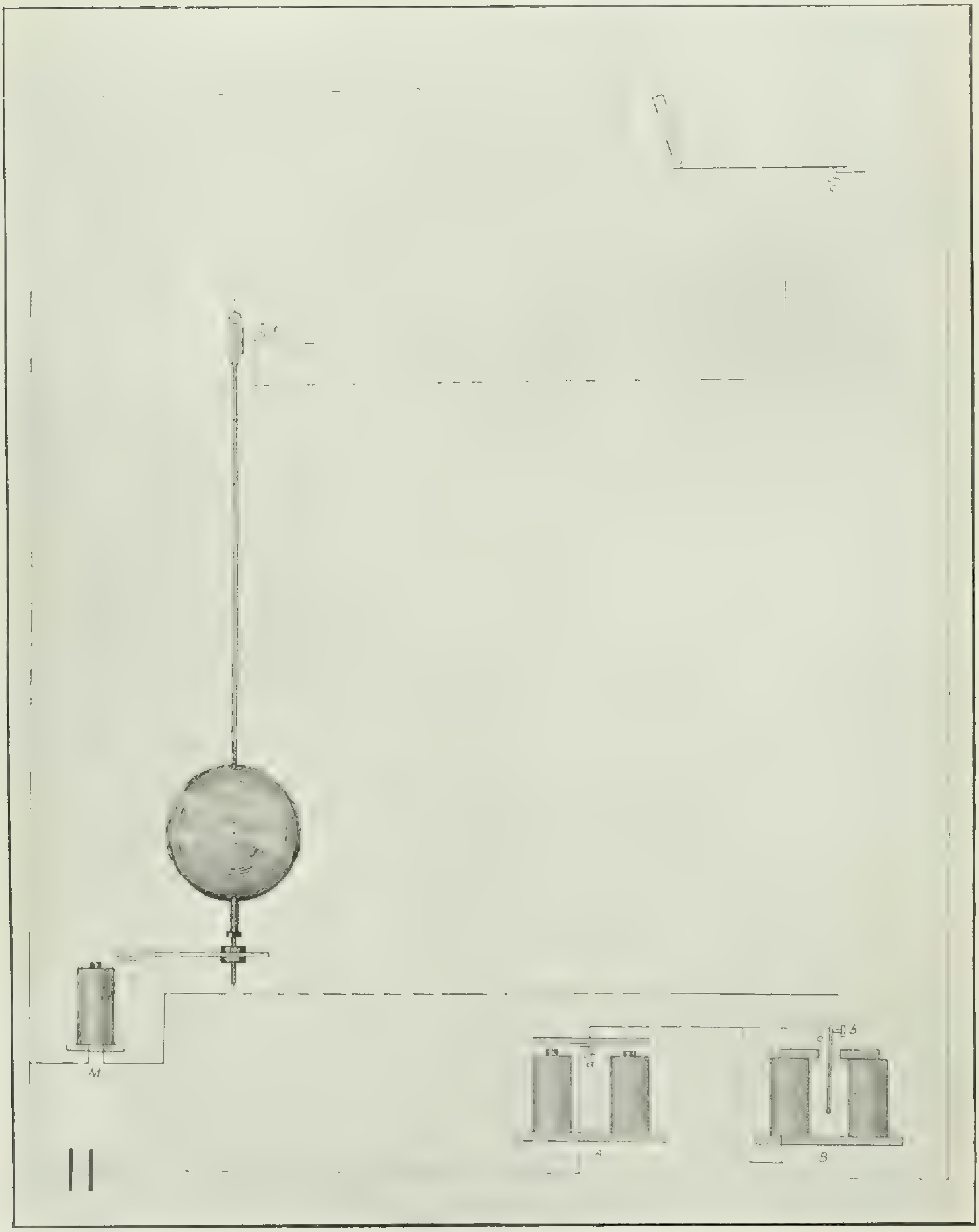
Reference was made in my last report to the proposed extension of the time service to the city Post Office, the Printing Bureau, the Mint and the Archives Building. The ownership of all the dials and electrical apparatus of the time service (with the exception of that in the Observatory itself) is vested in the Department of Public Works. For the sake of convenience, however, all the apparatus is ordered by the Chief Astronomer, after approval by the Department of Public Works; the electrical work, wiring, &c., is performed by the latter. After the work of installation is completed, the clocks are taken charge of by the Observatory, which becomes responsible for the attention necessary to their correct running.

The wiring in the Post Office was completed August 14, 1907, and on August 16 at noon the dials were started; the master-clock had been set up some time previously for the regulation of its rate; it was not put into synchronization until some little time later, when connection by wire with the Observatory was obtained. The movement of the tower clock was started on August 15, as soon as the storage battery had been charged, but the hands were left disconnected until August 24, the intervening period being taken up with testing and adjustment.

This Tower Clock is of the same essential type as the one at the Observatory, with a few improvements and modifications. The dial is six feet in diameter, in five sections of ground glass, retained in place by an iron frame-work in two sections, of which the hour and minute marks are an integral part. The hour marks instead of consisting as ordinarily of the Roman numerals, are single radial lines, thus taking up less space and enabling the time to be read at a greater distance. The illumination is arranged by a white enamelled reflecting-board the same size as the dial, and situated about a foot behind it; the light is thrown upon it from six 16 c. p. incandescent lamps arranged in a circle around its edge with suitable reflectors. The movement is driven by a small motor whose circuit is closed every minute by the master-clock; when the hands have been advanced the space of a minute the motor is automatically disconnected from the movement, and at the same time the circuit driving it is broken; the whole operation occupies perhaps half a second. The movement is connected to the hands by a driving shaft and universal joints.

To make the clock complete it seemed desirable to have an automatic switch for turning on the illumination in the evening and off in the morning. Time-switches are, of course, a commercial article, but on the suggestion of Dr. King, the much better plan was adopted of having the switch controlled by the clock itself. It was made and fitted to the clock in the Observatory work-shop, and has given absolute satisfaction. The 'switch' consists of two horizontal drop-levers operated by adjustable stops on a twenty-four-hour wheel which was added for the purpose. The upper lever is dropped in the evening by one of the stops, thereby making circuit with the lower lever through a carbon contact; in the morning the lower lever is dropped by the second stop and breaks the circuit; during the day the switch is again set by a pin on the twenty-four-hour wheel, which raises both levers simultaneously. By means of graduations on the wheel the stops can readily be set independently with considerable accuracy, so that the times at which the switch operates can be controlled within a few minutes.

About the time of the starting of the dials in the Post Office a request was received from the Ottawa Electric Company for permission to connect a clock to one of the government circuits. This privilege was granted them on condition of their extending the circuit to include the two dials in the Thistle Building on Wellington street, which had formerly been operated from the Langevin Block. The wires connecting the latter buildings consisted of too long a span for proper working, and in addition they passed over private property intermediate; consequently, it was con-



25a—p. 276.

Fig. 1 Synchronization Cut-out.

sidered better to operate the dials from the Post Office. The Ottawa Electric Company acceded to the condition and had the necessary wires erected; the circuit was then connected to the time service switch-board in the Post Office. The dial, a two-foot illuminated one, is situated outside the company's offices on Sparks street, together with an illuminated sign bearing the legend 'Dominion Observatory Time.'

The apparatus for the installation in the Printing Bureau, the Mint and the Archives Building was ordered in the beginning of February, 1907, and had all been received early in May. The dials in the Mint and the Archives Building were to be operated from the Printing Bureau, where the master-clock and switch-room were to be located, the former buildings being connected by wire with the latter. The wiring has, I understand, already been completed in the Mint and Archives Building. There still remains the equipment of the switch-room, the wiring in the Printing Bureau, and the placing of the clocks in position in all three buildings, as well as the erection of the connecting wires. As soon as this has been completed by the Public Works Department the system can be put in operation.

As mentioned in a previous report, the wires running from the Observatory to the buildings in the city, for synchronizing the secondary master-clocks, are rented from the Bell Telephone Company. There has frequently been temporary trouble on these wires, due, no doubt, in a great measure to the fact that, running as they do in cables with many other wires, and passing through the racks in the company's exchange, they are liable to be involved in inadvertent derangement by the constant repairs and alterations inseparable from a telephone system. It has been mentioned that with the system of synchronization in use no harm can result from the *opening* of the controlling circuit, as the synchronized master-clocks will in that case continue to run independently, though with less accuracy; but if it be *closed* without due precautions, if the phase-difference between the synchronizing and the synchronized clocks is excessive, there is a risk of stoppage of the latter. Hence a temporary derangement of the synchronizing line is a more fruitful cause of trouble than a permanent one, and is one of the principal contingencies to be guarded against. In the past, eternal vigilance has been the price of safety, and in spite of all precautions the inevitable has occasionally happened. As it was not practicable to establish an independent line, the only alternative was to instal a safety cut-out in connection with each master-clock, so that if for any reason it got too far out of step with the synchronizing current, it would automatically cut itself out of connection with the latter, and run independently until the proper conditions were restored. The cut-out arrangement consists of the pendulum-contact p (Fig. 1), in series with which and the points of the synchronization relay A is included a neutrally adjusted polar relay B; the local synchronization current passes in series through the points of the relays A and B and the synchronizing magnet M. Normally, during the alternate seconds while the synchronization current flows, the pendulum is performing that part of its swing which lies to the left of the vertical; if for any reason it gets sufficiently out of step that p and a are closed simultaneously, a circuit through B is established which opens the local synchronization circuit at b; since B is neutrally adjusted, it will remain open until closed again by hand. The auxiliary contact c, operated by the escapement, which is open for the first second of every minute, was made necessary by the fact that the synchronization current remains closed for three seconds at the even minute; otherwise the cut-out would act every minute, even when the clock was in step; the three-second interval in the synchronization current is for convenience in checking the coincidence of the master-clocks with the Mean Time Primary, and is also required for the proper operation of the check-dial at the Observatory. The contacts for the five master-clocks were made in the Observatory workshop, and they were installed, the first by Mr. Nugent and myself, the others by Mr. Nugent and Mr. Robertson. Their working has been quite satisfactory.

As in the past, the time has been supplied by telegraph every day to the Great North Western Telegraph Company, and by telephone to any parties requiring it.

A record was kept during the month of January of the number of requests for time by telephone, the accuracy desired varying from the simple hour and minute to the transmission of the actual clock-beats in the way described in my last report. The total number of calls during the month was 153, the maximum for any one day being 11. There were 8 requests for sidereal time, and 14 for the beats of the mean time clock. On one or two occasions during the year these beats have been sent over the long-distance line.

In the course of the longitude operations during the summer of 1907 it became necessary to arrange a circuit for recording the beats of the old Borrel master-clock on the chronograph, which involved the installation of a suitable contact. The type of contact required was the usual one for chronographic registration—that is, it was required to break circuit every alternate second, omitting the 58th. These contacts are usually operated by the escapement, but in this case the beats of the clock were not entirely uniform throughout the minute, the escapement being of the pin-wheel type, which is particularly liable to this defect. It was necessary, therefore, to operate the contact by the pendulum; for this purpose a simple but efficient contrivance was adopted, which may be worth describing. The contact was situated about one-quarter way down the pendulum from its point of support; a sketch showing it as viewed from behind is shown in Fig. 2. The block *b* and the contact

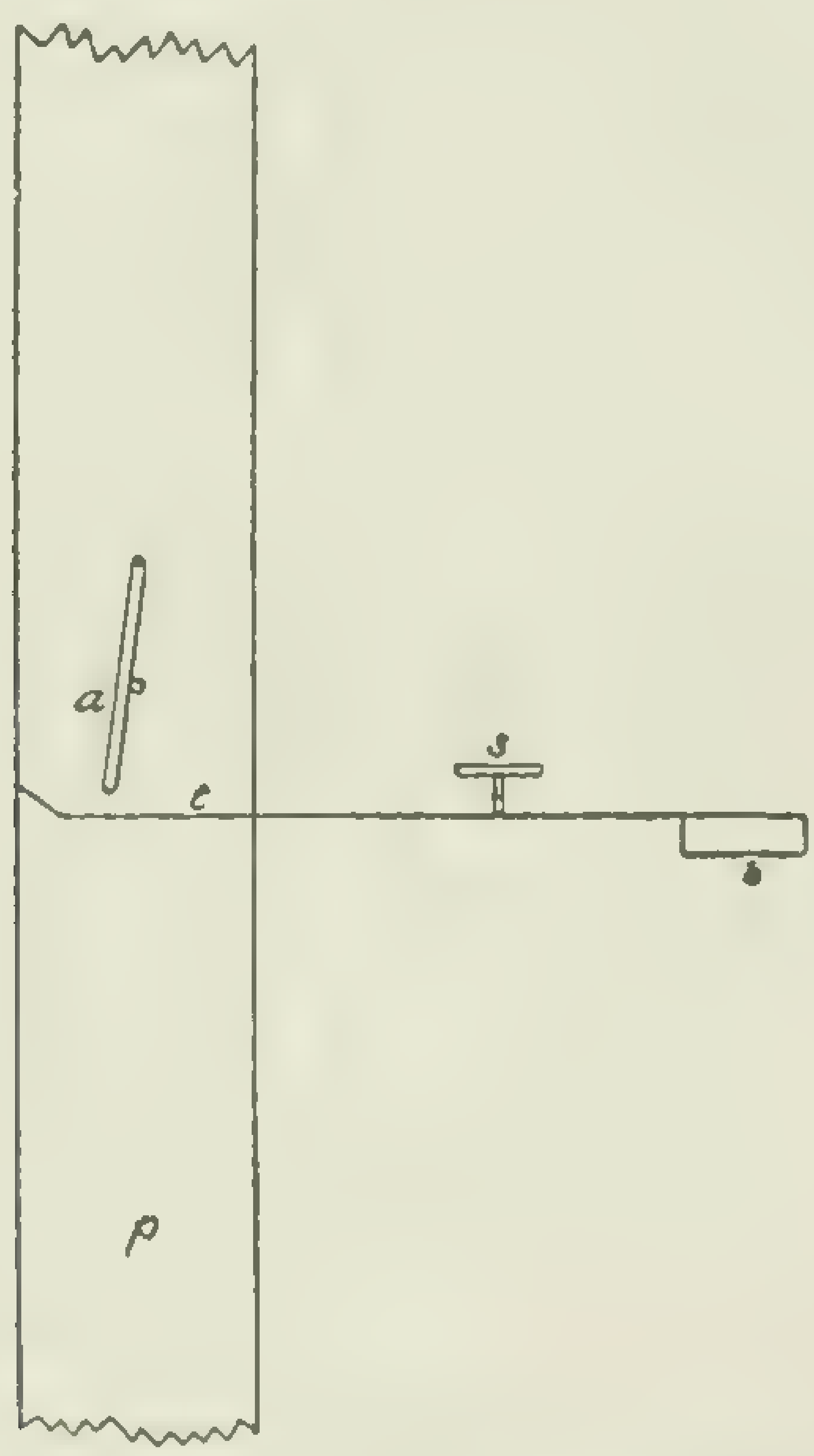


FIG. 2—Pendulum Contact.

screw *s* are attached to the back of the clock-case; *t* is a very light spring attached to *b*, and terminating at its free end with a slight upward bend. Attached to the pendulum rod *p* is a light arm *a*, pivoted to swing freely about a point near its upper extremity, and resting against a stop at one side. As the pendulum swings to the left *a* engages with the point of *t*, depressing it so as to break the circuit at *s*; on the swing to the right *a* is lifted clear of its stop and does not depress *t*. The omission of the break at the 58th second is managed by a wheel connected to the escapement, which short-circuits the contact from the 57th to the 59th second. In order not to affect the going of the clock the whole contact, especially the spring *t*, must be of very light construction.

After a prolonged delay, a considerable part of which was due to the fact that the consignment went astray in shipment, the seconds-dials for use in the Observatory have at last been received. Three of them will be operated by the sidereal master-clock, one in the equatorial room, one in the transit room and one in the meridian circle room; the remaining four will be operated by the mean time signal clock, being distributed through different rooms in the building. Already two of them (one sidereal and one mean time) have been mounted in the equatorial room; only the sidereal one is as yet in operation. They are operated by a reversal of the current every second, and are very satisfactory in their working; they have a resistance of about 160 ohms each, and can be operated in parallel by a battery of four volts.

During February and March a test was made of the eight-box chronometers belonging to the Observatory, which are used for the field work. No chronometer room has as yet been fitted up at the Observatory, so that the temperature could not be controlled very satisfactorily, nor could as large a range be obtained as was desired. The chronometers were placed in the pendulum room, and connected by wire with the time room, where the comparisons were made daily with the sidereal clock by chronograph. The temperatures obtainable were practically restricted to two, according as the steam coils in the room were opened or closed; in field work the temperatures experienced are very much more varied, ranging from below freezing point to sometimes 95° or 100° F, a considerable proportion of this range being occasionally covered within a single day.

During the course of the test the chronometers were tested for magnetic polarity by turning through an angle of 90°; in only one case (Dent 52865) was there a marked change in rate during this period, and even in this case the change was much less than occurred during other portions of the test. During one period of 48 hours comparisons were made every 2 hours, to determine whether there was any change of rate depending on time elapsed since winding; no such change was noticeable in any case. The running of the chronometers on a 48 hour winding was also tested in a similar way, but these rates were not used in working out the trial numbers. The trial numbers are intended as an indication of relative accuracy, the chronometer giving the smaller trial number being in general the more accurate. The particular way in which the different mean variations given by the test are combined to form the trial number is of course merely arbitrary, and if two chronometers have trial numbers nearly equal it does not necessarily follow that the trial numbers are an exact guide. They have been formed in the present instance as follows: In the column 'Mean periodic variation' (Table I) is given the average difference (without regard to sign) between the mean rate for the whole test and that for each of the periods given; to this is added the average of the mean daily variations for the different periods, and the mean variation for two hours as given in the ninth column. This sum is taken as the trial number.

TABLE I. TESTS OF CHRONOMETERS.

Chronometer.	Feb. 14–Feb. 21 Mean daily rate.	Feb. 14–Feb. 21 Mean variation.	Feb. 23–Mar. 1 Mean daily rate.	Feb. 23–Mar. 1 Mean variation.	Mar. 4–Mar. 11 Mean daily rate.	Mar. 4–Mar. 11 Mean variation.	Mar. 9–Mar. 11 Mean rate for two hours.	Mar. 9–Mar. 11 Mean variation.	Mar. 11–Mar. 15 Mean daily rate.	Mar. 11–Mar. 15 Mean variation.	Mar. 15–Mar. 19 Mean daily rate.	Mar. 15–Mar. 19 Mean variation.	Mar. 19–Mar. 27 Mean daily rate.	Mar. 19–Mar. 27 Mean variation.	Feb. 14–Mar. 19 Mean daily rate.	Feb. 14–Mar. 19 Mean periodic variation.	Trial Number.
Bond 511*	2·26	08	2·07	11	2·33	·08	19	02	2·25	19	2·43	·04	2·33, 2·32	10, 21	2·24	·10	22
Bond 593	26	22	78	16	17	·14	03	02	·34	·16	44	10	33, 59	14, 42	37	25	43
Bond 516	2·60	18	3·08	·24	2·45	10	20	01	2·31	16	2·29	13	1·96, 1·86	15, 13	2·63	26	43
Dent 48419	37	60	25	12	31	11	·02	·04	20	48	05	·07	50, 1·19	07, 09	08	22	54
Negus 2088	55	12	2·10	04	1·01	08	07	01	91	05	94	18	81, 69	11, 06	1·19	45	55
Dent 52866	4·07	23	2·74	24	3·16	11	28	02	3·68	·19	3·42	·12	3·27, 2·94	17, 07	3·37	38	58
Dent 52865	2·71	·54	1·14	57	37	40	06	05	1·06	06	18	40	35, 75	37, 12	85	1·32	1·76
Hadlock 4082	1·31	68	4·15	83	1·37	44	12	02	1·55	21	2·25	86	2·39, 2·62	66, ·75	03	2·11	2·73
Mean Temp.	59		84°		61		60		59		58		55				
Max. "	61		90		63		62		60		60		57				
Min. "	57		77		58		58		58		56		53°				

* Mean time Chronometer.

March 9–March 11.—Comparisons made every two hours.

March 11–March 15.—Chronometers turned through a right angle to test for magnetic polarity.

March 15–March 19.—Chronometers replaced in original position.

March 19–March 27.—Chronometers wound only on alternate days. The two rates are the means respectively of the rates for the first and for the second 24 hours.

February 14–March 19.—These columns contain the mean rates and mean variations for the whole period up to March 19.

Trial number.—This is the sum of three quantities: (1) the mean variation in the second last column; (2) the mean of columns 3, 5, 7, 11, 13; (3) the mean variation in column 9.

SECTION II.

REPAIRS AND ALTERATIONS TO FIELD INSTRUMENTS.

During the summer of 1907 a travelling-wire micrometer, or transit micrometer, was made in the workshop and fitted to Cooke Transit No. 1. It was modelled for the most part, with a few alterations, on the Saegmuller micrometers already in use on Transits No. 2 and No. 3. The general type of construction of transit micrometers is now becoming so well known that it is unnecessary to describe it here in detail.* The spider lines, two parallel and one perpendicular to the micrometer screw, are attached to a slide which is moved by the screw; on the head of the latter are fixed several contact strips which make contact with a spring as the screw is turned, thus furnishing the records on the chronograph. A spiral thread of a few turns which is also attached to the micrometer head operates a small graduated wheel for counting the number of revolutions; attached to this is a flange with a notch of a length corresponding to four revolutions of the screw, which operates a cut-out lever so that only the record of those four revolutions reaches the chronograph. The adjustment for collimation is made by a dove-tailed slide supporting the whole micrometer box; another slide at right angles to this is also provided, while the whole micrometer is arranged to turn between stops through an angle of 90° in order that it may also be used for measuring differences of zenith distance. The eye-piece is mounted on an independent slide whose motion is controlled by a separate screw. The micrometer is driven through a gear wheel by a pair of driving-heads worked by both hands, one revolution of the driving-heads corresponding to two revolutions of the micrometer.

In the usual type the cut-out is so arranged that the record is made by the four turns in the centre of the field; in this instance, however, for reasons described below (see Section IV), it was desired to record every alternate four revolutions throughout the field. It was also decided to have the eye-piece slide driven at the same speed as the micrometer wire, so that while observing the wire would appear stationary in the middle of the field. It seemed likely that in this way there would be less danger of systematic error due to apparent motion of the star and wire across the field. An auxiliary adjustment was also provided by which the eye-piece could be moved independently by hand as before.

As a matter of fact, the micrometer is yet unfinished in many details. At the time of making, it was desired for several reasons to get it into commission as soon as possible, and for this reason all non-essentials, such as polishing, lacquering, and even the careful finishing up of some of the merely auxiliary parts, such as the eye-piece slide, &c., were dispensed with, and the instrument pressed into service as soon as it was in a condition to do efficient work. It had been hoped to have it ready for work by the beginning of September, but for some reasons into which it is not necessary to enter here, it was delayed for a full month, being used for the first time on the first of October. On account of pressure of work in the machine shop it has been left in the same condition up to the present; it is hoped, however, to have it completed in the near future.

The operation of the instrument will be readily understood from Fig. 3, which is reproduced from a photograph. The micrometer screw, rigidly attached to the micrometer head *a*, is operated by the large gear wheel mounted on the shaft of the driving heads *bb;* near the other end of the same shaft is a small gear-wheel meshing into the wheel *c*, the gear-ratios being so arranged that *c* makes one revolution for every eight of the micrometer screw. Extending half-way around *c*, near its outer edge, is a flange which engages with the lever *d;* the other end of this lever, on which is an insulating knob, operates the spring *e*, lifting it off the contact screw *f* (mounted

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* For a more detailed description see Report of the Chief Astronomer for 1905. Appendix 2, by Otto J. Klotz.

on an ebonite block) when d engages with the flange on c. The circuit is thus closed through e f during every alternate four revolutions of the micrometer screw. One end of the observing circuit is led to f, and, providing e f is closed, it is continued thence through the wire g to the platinum-tipped contact brush h; this brush, as the screw is rotated, makes contact with five platinum strips let into the ebonite head i; these strips are connected to the body of the micrometer box and so to the telescope, which forms the return circuit. The eye-piece slide l is moved by the screw m, which is operated from the small wheel attached to c; the pitch of the screw is sixteen turns per inch, and the gear-ratios are so adjusted that the rate of motion of the eye-piece is the same as that of the carriage driven by the micrometer screw, which carries the spider lines. An independent motion of the eye-piece slide is also provided by means of a rack and pinion which moves the nut n with relation to the slide l. A screw adjustment for focussing the eye-piece was also provided; the tube into which the eye-piece slides is made in two sections, one of which screws into the other; after adjustment of the focus has been once made the maintenance of their relative positions is insured by a lock-nut; the necessity is thus avoided of refocussing every time the diagonal eye-piece is turned from one side of the instrument to the other. In the usual type of micrometer there is a comb with five teeth in the field of view, which marks the four revolutions of the screw which correspond to the centre of the field. This was replaced by a comb in four sections, each of which was similar to the above; the four sections were set symmetrically with respect to the centre of the field, and the cut-out arrangement so adjusted that the record on the chronograph was made while the spider-thread was passing over the several sections of the comb.

In other respects the micrometer is practically identical with those on Transits No. 2 and No. 3. The original cut-out (corresponding to four revolutions of the screw) was not omitted, as at that time it was a question whether the contemplated methods of observation which made the new one necessary would prove practicable, and it was not certain which would finally be used. The micrometer screw has a pitch of 120 turns to the inch; the thread was first cut as carefully as possible in the lathe, and the periodical and other errors eliminated by prolonged grinding in suitable nuts, first with fine emery and at the last with rouge.

The Y's of Cooke I, for the support of the axis, formerly consisted each of two cylindrical segments, so that each bearing surface extended through an arc of about 45° around the circumference of the pivot, and over a space of nearly an inch longitudinally. This form, a very undesirable one, was altered so as to conform to the recognized pattern. A section through the Y by a plane perpendicular to the axis now consists of two segments of straight lines perpendicular to each other, and each inclined 45° to the horizon; a section by a plane passing through the axis and perpendicular to one of the above lines is a curved line very slightly convex towards the axis. This constitutes the nearest practicable approach to the ideal 'two-point' bearing.

This transit has never been used as a zenith telescope, being always reserved as the home instrument in longitude operations. As soon, however, as the Meridian Circle is available for regular observations, Cooke I will be freed for field work, which makes necessary some further alterations for its adaptation as a zenith telescope. These are to be made in the near future, and consist of the addition of a mounting for a latitude level, and the installation of new slow-motion zenith-distance tangent screws, the ones now in place being too coarse for fine adjustments. At the same time it is proposed to raise the standards so that the instrument may be transited eye-end down, which is at present impossible.

After a thorough test of the new micrometer it was recommended to Dr. King, for reasons given in Section IV of this report, and approved by him, that the cut-outs on the micrometers of the two other transits should be altered so as to conform to the principle embodied in the new one. In these micrometers no provision is made for

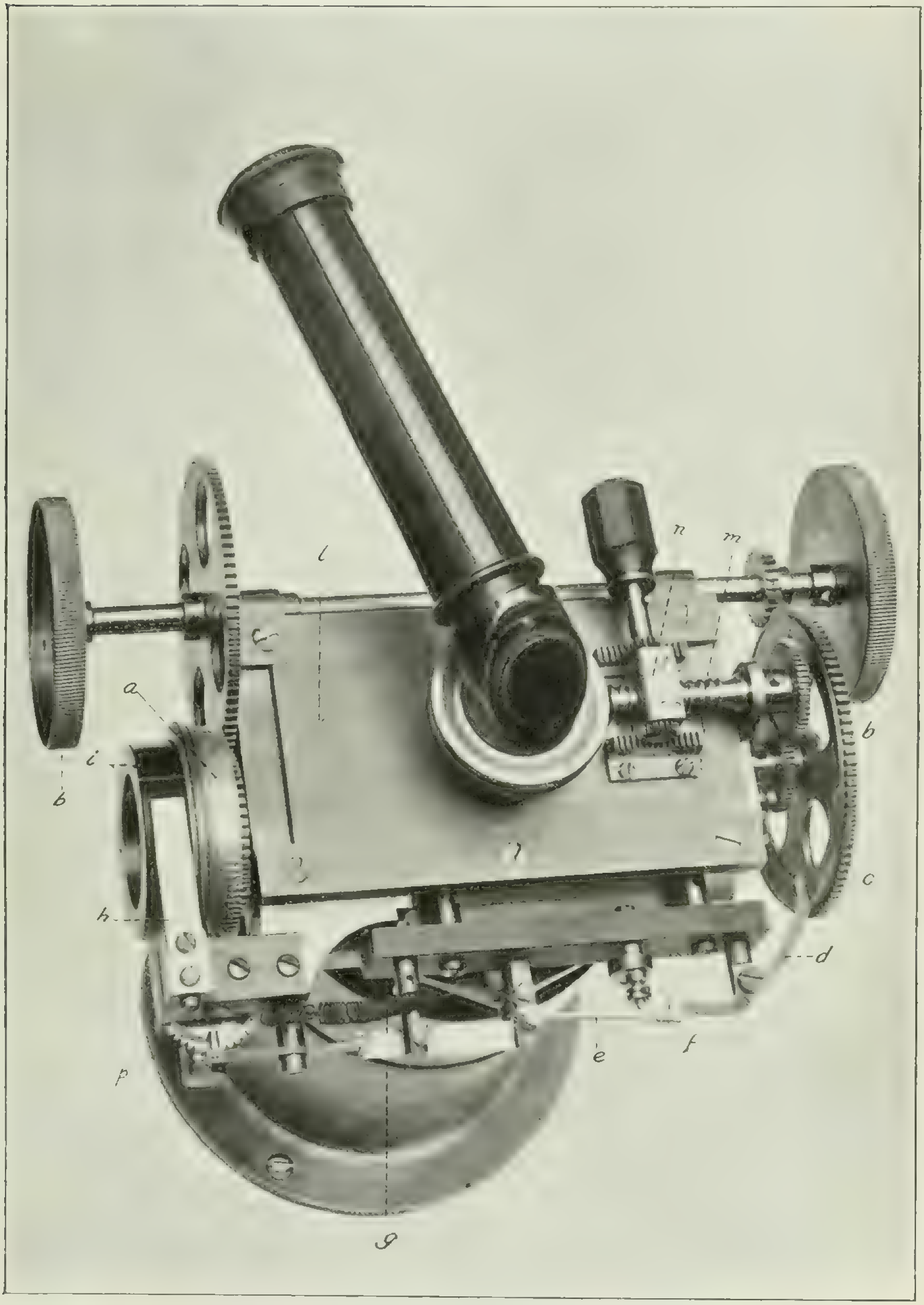

FIG. 3.—Transit Micrometer.

the motion of the eye-piece with the spider-line carriage, only the independent movement being provided; consequently, the wheel *c* is lacking. As the introduction of this wheel would have necessitated further alterations which were rather inconvenient, it was decided to dispense with the driving of the eye-piece slide, and to attempt to provide for the increased number of records on the chronograph by a simple alteration of the existing arrangement. The flange attached to the small counter-wheel (*p*, Fig. 3) was removed, and a new one containing four notches made to replace it. It was feared at first that owing to the smallness of the flange and the necessity for having the notches exactly the correct width and at the correct interval, this might be difficult to accomplish; however, after several attempts it was successfully done. The number of notches was limited to four, because it had been found that a larger number of records would never be required. New combs were also made, similar to the one in Transit No. 1. These combs being extremely minute (the distances between contiguous teeth being in one case 1/120-inch, in the other 1/130-inch) were difficult to make without special appliances, and a very neat method was suggested by Mr. Mackey, our ingenious mechanician. The thin strip of brass from which the comb was to be made was inserted in a slot in a cylindrical rod and the whole hammered well together; it was then inserted in the lathe, turned down till the whole was an apparently homogeneous piece, and a thread of the proper pitch cut; to cut out the spaces between the sections of the comb the lathe-carriage was moved along the ways by the driving screw to the proper position, disconnected from the latter and a cut of the proper depth taken; it was then connected again to the driving screw, moved along the proper distance (eight revolutions) and another cut taken, this process being repeated the required number of times. On releasing the brass strip from the slot in which it had been held, the finished comb dropped out.

The chronographs used in the field operations are of the small Fauth (now Bausch and Lomb) type. The governors are driven by a spiral gear, consisting of a thread of low pitch cut on the shaft of the governors, which engages with a gear wheel in the train. This has always proved more or less unsatisfactory, and last summer one in particular of the chronographs absolutely refused to work. The spiral gear was taken out, an extra wheel inserted in the train, and a bevel gear introduced to drive the governor-shaft. This has worked so well that it has been decided to make the same alteration in the other chronographs; work on this is now in progress.

SECTION III.

THE MERIDIAN CIRCLE.

The Meridian Circle, for which an order had been placed some years ago with Messrs. Troughton and Simms, was received on October 28 last, and the work of setting up and adjusting was immediately proceeded with. The telescope is of six inches aperture and about seven feet focal length; the field contains six fixed vertical threads and two horizontal ones, in addition to the movable micrometer threads; the right ascension micrometer is supplied with the Repsold automatic registering device. The field illumination is provided for by an annular reflector in the axis; bright wire illumination is effected by four small electric lamps inside the tube near the eye-end. There are two circles, each graduated to every five minutes, one being fixed in position on the axis, the other movable. They are read by four microscopes each, two pointer-microscopes (one for each circle) being also provided for reading to the nearest five-minute division. There is an end-thrust bearing at each end of the axis, one being fixed, while the other is tightened by two nuts pressing against coil springs; this ensures the constancy of the position of the telescope with respect to the standards, so that the division marks may always be in focus in the reading-microscopes. There are two collimating telescopes, each of four inches aperture and about four and a half feet focal length. For reversing the telescope a reversing carriage is provided, which runs on rails laid between the piers. The level is read by nadir observations

on a circular mercury trough with the usual type of collimating eye-piece; there is also another mercury trough mounted on wheels, for observation of stars by reflection. In addition, the usual complement is provided of extra eye-pieces, apparatus for testing pivot errors, &c.

The piers for the support of the instrument and collimators had been built previously; they all rise from the level of the foundation walls of the building. The two instrument piers are supported by a single base which terminates about 18 inches below the level of the floor. On attempting to mount the instrument it was found that owing to the height of the reversing carriage the piers were considerably too low. After this had been remedied the instrument was mounted and got in approximate adjustment about the beginning of December. After the adjustment it was discovered that the piers were not altogether free from the concrete floor, a certain amount of soft concrete having apparently become lodged in the spaces and hardened there: after this had been cut away it was found that the level error had changed from about 3 seconds of arc to about 12 seconds. Further adjustment, however, was postponed until later, and the level error remained about this value for some time.

On putting the reading microscopes into position and attempting to adjust them it was immediately apparent that there was some defect in the circles, as the microscopes when focussed for one zenith distance did not remain in focus as the telescope was revolved. This might have been due to any one of three causes: (1) a lack of trueness in the fixed end-thrust bearing, causing a slight motion east and west of the telescope as a whole when revolved; (2) a lack of perpendicularity between the plane of the circles and the axis of the telescope; (3) a deviation of the circles themselves from the true plane form.

To test the first hypothesis, which, however, seemed unlikely in itself, one of the microscopes was mounted so as to view longitudinally the centre of one end of the axis, and the telescope was revolved. As the stationary point in the axis remained truly in focus during the whole revolution, the possibility of the first cause was eliminated. The next step was to determine the deviation of the graduation bands of the circles, around their whole circumference, from a true plane at right angles to the axis of rotation. For this purpose one of the western microscopes was removed from its mounting, and replaced by two cylindrical brass bearings; in these a steel rod was arranged to slide so that one end could readily and surely be brought into contact with the silver strip on which the graduations were ruled. The microscope which had been removed was mounted with its line of sight perpendicular to the steel rod, upon which was engraved a mark to be viewed by it. To test the circles, each required point was brought opposite the rod, which was then brought into contact with the circle, and the micrometer of the microscope set on the engraved mark. This was first done for every 20° around the fixed circle; the telescope was then reversed and the same process repeated with the movable circle. A microscope was then dismounted from the eastern pier and similar measurements taken from that point on both circles, the division marks set on in this instance being intermediate to those tested previously. Finally the value of one turn of the micrometer was determined (about ·134 mm.), and the displacements from the mean plane reduced to millimetres. These displacements are shown in tabular form in Table II, and graphically in Fig. 4, in which the ordinates, representing the displacements, are magnified 25 times. The smoothness of these curves, as well as the interagreement of the series of readings in Clamp West and Clamp East for both circles, indicate the delicacy of this method of measurement.

It was now evident that the trouble lay in a distortion of both circles, and, from the existence of two maxima and two minima and their relative positions, that the distortion consisted in a simple bend along a line passing nearly, but not quite, through the centre of each circle. As the relative position of the two circles in the packing box had not been noted at the time of unpacking, it was not known whether these lines had coincided at that time; it appeared likely, however, that the damage had been caused by rough handling in shipment.

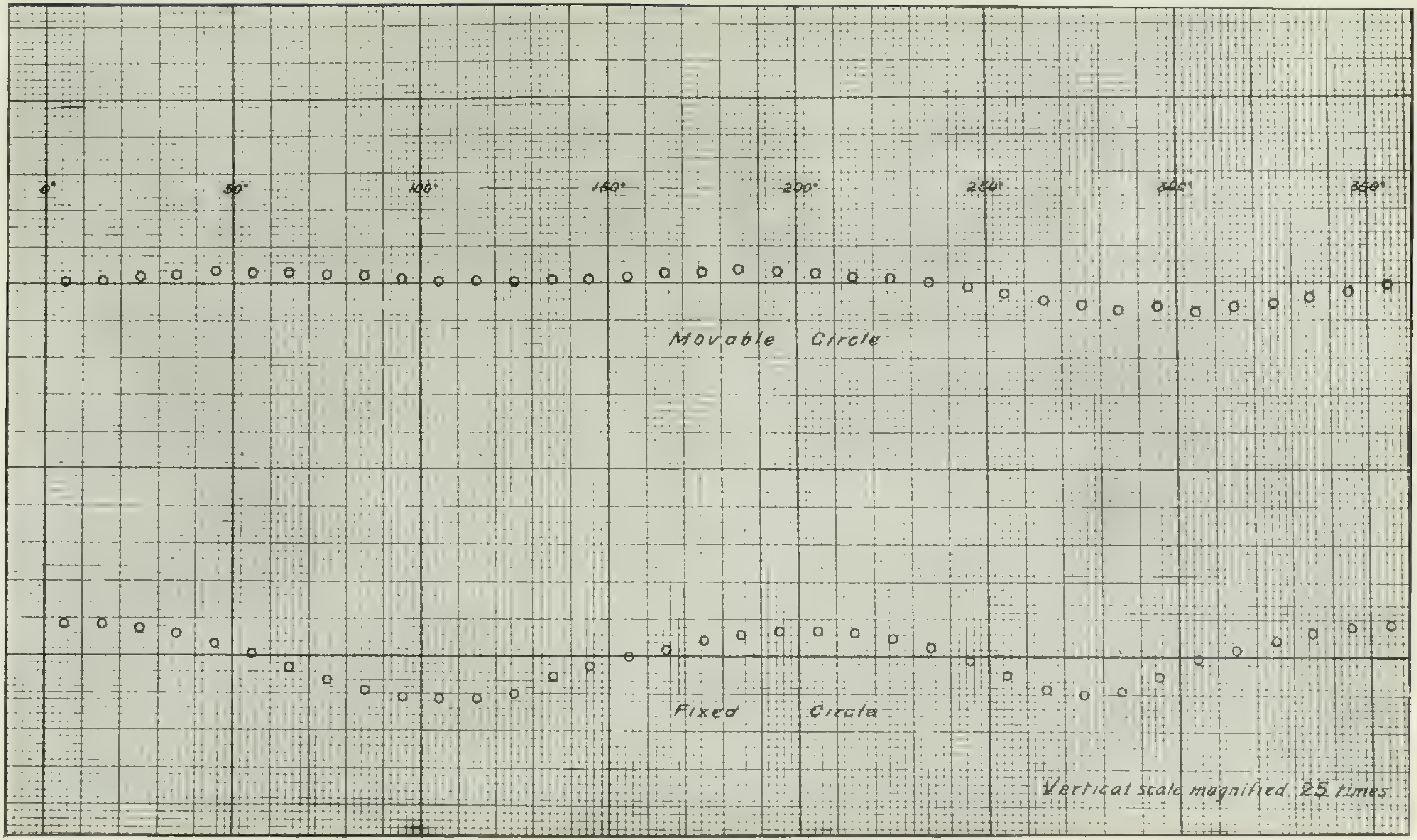

FIG. 4 Errors of graduated circles.

The above facts were communicated to Messrs. Troughton and Simms, who decided that it would be necessary only to return them the circles, together with a pair of microscopes for testing. They were accordingly shipped on January 16, and are still in the makers' hands.

The weather during December and the early part of January was very poor astronomically, but as often as possible observations were taken for the purpose of testing the instrument; as the circles were useless the observations were, of course, mainly confined to transits. The right ascension micrometer was found not to work very satisfactorily, but was improved by cleaning and by the insertion of a stronger spring; some minor adjustments were also found necessary. Such observations as were made were carried on under considerable difficulty, as the electric wiring for the meridian circle room has not yet been done. A pair of wires was strung temporarily from the time room to afford connection with the chronograph; another pair led to a single electric light; this, together with an oil lantern, furnished the only means of illumination for telescope field, collimators, nadir eye-piece, setting circles, &c. The specifications for the wiring have been in the hands of the Public Works Department for about a year, but nothing has been done as yet. It was necessary also to open and close the roof-shutters by hand, as the opening mechanism had not been provided. Work on the latter was begun early in January, and as the necessary scaffolding interfered with the sky-view, the use of the instrument had then to be discontinued.

The roof-shutters in the meridian circle room consist of nine sections; the two openings in the transit room are closed by shutters of six sections each. When the opening mechanism was being planned it was considered best to join these sections in groups of three, giving three independent shutters in the meridian circle room, and two for each opening in the transit room. The shutters will be controlled by counterpoised levers which can be operated by a winch on the wall. The mechanism for the middle shutter in the meridian circle room has been installed, and works satisfactorily. The original iron wall-shutters, six in all, have proved to be entirely useless, both because they do not exclude the snow and rain, and because they have become in some cases so warped that they will not open and close. One of them has been experimentally replaced by a wooden shutter which gives promise of satisfactory working. There are also many other details in the building which require alterations and repairs; it is hoped that work will be pushed on them during the coming summer.

When the scaffolding had been removed from the meridian circle room after the erection of the shutter mechanism, the instrument was overhauled and got ready for work. It was speedily discovered, however, that a decided shifting of the piers had taken place; the level error, which had previously been about 12 seconds of arc, had now increased to over three minutes; on examination the shifting was apparent to the eye in the uneven spacing between the piers and the floor on opposite sides, which had before been fairly uniform. The collimation axes of the collimators were also out of line by several minutes of arc, both in altitude and azimuth, showing a relative displacement of their piers. The main instrument piers had been tilted towards the west, that of the north collimator towards the north, while the shifting of the south collimator was not so evident, though no doubt considerable. It had been discovered a day or two previously that the two instrument piers and the two collimator piers in the transit room had been fractured in the basement; this was evidently due to upheaval of the bases, resulting in a lateral pressure against the concrete floor above; the latter, being reinforced by steel girders, had withstood the strain, and the piers had given way. The cause of the upheaval was traced to the action of frost; the meridian circle piers had apparently been saved from absolute fracture by the fact that they were surrounded to a certain height by loose earth; the floor of the basement of the transit room was, on the other hand, of concrete. It will be necessary to reconstruct all seven piers, sinking their bases several feet further into the earth, to guard against a repetition of the upheaval. The approximate level error of the meridian circle is shown in Table III for a number of dates throughout the winter.

It is proposed during the coming summer to erect piers for azimuth marks north and south of the meridian circle. The primary marks will be fixed underground for stability, while on the piers will be movable marks, which can be set vertically over the underground ones by a process similar to that used at the Royal Observatory, Cape of Good Hope. This, it is hoped, will furnish marks whose absolute stability can be relied on for considerable intervals, if not permanently. The collimating lenses for these marks, situated within the building, will also be movable, for adjustment over similar marks.

An observing couch has been designed, and the order has been placed for its construction. It will run on the same rails as the reversing carriage, and will comprise mechanism for quick setting in any desired position, combined with a slow motion for the final adjustment.

A detailed description of the meridian circle, with all its accessories, is reserved until the equipment is completed, as a considerable part of the apparatus is as yet not installed, and in some cases indeed not yet definitely planned.

TABLE II.—ERRORS OF GRADUATED CIRCLES.

Division Mark.	Displacement. Movable Circle. Clamp W.	Movable Circle. Clamp E.	Fixed Circle. Clamp W.	Fixed Circle. Clamp E.
5	·01 mm.		·17 mm.	
15		·02 mm.		·17 mm.
25	·05 mm.		·15 mm.	
35		·06 mm.		·12 mm.
45	·08 mm.		·07 mm.	
55		·07 mm.		·01 mm.
65	·07 mm.		—·06 mm.	
75		·06 mm.		—·12 mm.
85	·05 mm.		—·18 mm.	
95		·03 mm.		—·22 mm.
105	·01 mm.		—·23 mm.	
115		·01 mm.		—·23 mm.
125	·01 mm.		—·16 mm.	
135		·02 mm.		—·10 mm.
145	·02 mm.		—·05 mm.	
155		·04 mm.		·00 mm.
165	·06 mm.		·04 mm.	
175		·07 mm.		·09 mm.
185	·08 mm.		·12 mm.	
195		·07 mm.		·14 mm.
205	·06 mm.		·14 mm.	
215		·04 mm.		·13 mm.
225	·03 mm.		·10 mm.	
235		·00 mm.		·05 mm.
245	—·02 mm.		—·02 mm.	
255		—·05 mm.		—·09 mm.
265	—·08 mm.		—·17 mm.	
275		—·11 mm.		—·20 mm.
285	—·14 mm.		—·18 mm.	
295		—·12 mm.		—·10 mm.
305	—·15 mm.		—·02 mm.	
315		—·12 mm.		·04 mm.
325	—·10 mm.		·09 mm.	
335		—·07 mm.		·14 mm.
345	—·04 mm.		·16 mm.	
355		—·01 mm.		·17 mm.

TABLE III.—LEVEL ERROR OF MERIDIAN CIRCLE.

Date.	Level Error.	Date.	Level Error.
December 12	— 3·6″	January 5	—11·3″
" 13	— 3·4″	" 9	— 9·0″
" 19	— 2·6″	February 22	—3′ 19″
" 21	—12·4″	March 8	—5′ 17″
" 26	—10·4″	" 14	—5′ 39″
" 28	—11·6″	" 22	—5′ 41″
January 3	—11·3″	" 30	—5′ 50″

SECTION IV.

ERRORS OF TRANSIT OBSERVATIONS.

An account was given in my last report of a series of observations undertaken as a comparison of the relative accuracy of transits with the key and with the transit micrometer. The comparison was based on an investigation of the discrepancies occurring between successive time determinations made on the same night by the same observer with the same instrument; it showed that after allowing for the systematic personal equation of the key observations, there was, as regards accuracy, very little to choose between the two methods of observation, and that consequently the ordinary explanation of these discrepancies (by the assumption of rapid fluctuations of personal equation) is probably in error, since presumably these fluctuations, if existent at all in micrometer observations, would be very much reduced, as is the personal equation itself. These conclusions were supported by the examination of such other micrometer observations at the Observatory as were available. It was added that this could not be taken as invalidating the claim of superiority for the transit micrometer, since it has never been disputed that personal equation, perhaps the greatest bugbear of transit observations, is at least very materially reduced by the use of the micrometer. It was pointed out, however, that the discrepancies common to both kinds of observations were much larger in comparison with the nominal probable errors obtained in the usual way, than should be the case. From an examination of nearly a hundred nights' work, the average discrepancy between two sets taken on the same night was found to be ·039 sec., a value which was shown to be equivalent to a probable error of about ·025 sec., while the average probable error as obtained from the residuals of the separate stars was ·011 sec. This showed that, in addition to the irregular errors which show themselves as residuals, there must be some other source of error, systematic with respect to any one set, but varying from one set to another.

It was suggested that this might be due to defective determinations of azimuth arising from ordinary accidental errors of observation of polars; since only two polars were observed in each set, it would likely not infrequently happen that the errors in both these might be fairly large and of the same sign; this granted, the observed effect would follow. From the few suitable observations which were available at that time, it was shown that by observing several polars in a set, and selecting them in separate pairs for combination with the south stars, the results could be varied by quantities ranging up to ·07 sec.; this was taken as a provisional confirmation of the hypothesis. It may be stated here that this result has been fully confirmed by later and more extensive observations.

If, then, the cause at which we have arrived be the correct one, and assuming also that the portable instruments are fairly stable during the course of a single evening, we should expect that on those nights when the discrepancies are large they would be reduced if we could increase the precision of the azimuth determinations. This test has been applied in the following way: From all the observations examined previously, the ten nights were selected which showed the largest discrepancies. All the observations on each night were reduced together for a single value of azimuth and collimation; this value of the azimuth should evidently be better (if the instrument were stable) than either of the values previously applied in the reduction of the sets separately. Finally, a value of the clock correction was found from the south stars of each set separately, by applying this value of azimuth and collimation to all. The effect of this method of reduction is shown in Table IV. The second and third columns show the clock corrections as originally determined, and the discrepancies between the different determinations on the same night; the fourth and fifth columns show the same quantities after employing the reduction mentioned. The discrepancies are materially reduced in every case, the reduction varying from 40 per cent to 86 per cent; the average of all is reduced to one-third of its former value. No more

unequivocal proof could, I imagine, be found, that these discrepancies are for the most part due to defective determinations of azimuth, and that any method of observing that can be devised to strengthen the azimuth will materially increase the average accuracy of time observations. As will be seen below, theory also supports the conclusion that the ordinary distribution of stars in a time set will not give the most satisfactory results.

The simplest way to strengthen the azimuth determination would, of course, be to increase the proportion of polars observed, but unfortunately the number of polars in the standard catalogues is rather scant; it was thought possible, however, that by increasing the number of observations on each star a similar effect might be gained. It was for the purpose of experiments along this line that the special cut-out was attached to the micrometer made for Cooke Transit No. 1. Four revolutions of the micrometer correspond to an equatorial interval of about 13 seconds; the time required for an observation of a star of 75° declination would thus be nearly a minute. There is no doubt that any great extension of this time would result in undue fatigue of the eye, and tend to lessen the accuracy of at least the latter part of the observation; if, however, several observations of this duration are made, separated by about the same interval, this fatigue does not result, as was evident from some preliminary experiments. In addition, observations so taken would be independent in another way, since ample time would be allowed between observations for re-focussing, adjustment of illumination, &c. Also, the instrument could be reversed during the observation of each star, involving an elimination of collimation error, as well as a simplification of the computation.

It was decided to make the observations in the following way: For polars, the observation began at 14 rev. from the centre of the field, continuing to 10 rev.; then after an interval of 4 rev. it was repeated from 6 rev. to 2 rev.; the instrument was then reversed and the observation completed over the same parts of the screw as before. For south stars, on account of their swifter motion, it was possible to observe only from 14 rev. to 10 rev., in order to allow sufficient time for reversal.

The new micrometer was used for the first time on October 1, 1907. During the month of October, in connection with the longitude operations then in progress, two time-sets were taken on every clear night, each set consisting usually of three or four polars and from six to eight south stars. Throughout the winter it has been used whenever necessary for the determination of clock-error. On October 8, October 15 and October 30, observations of as many polar stars as possible (at either upper or lower culmination) were made in addition, in order to determine whether the probable error was materially reduced by the new process. Denoting the times of the four observations of any star (in the order made) by T_1, T_2, T_3 and T_4, it is evident that any one of these is the equivalent of (or indeed *is*) an ordinary observation without reversal, affected by errors both of azimuth and collimation; also, the quantities $\frac{T_1 + T_4}{2}$ and $\frac{T_2 + T_3}{2}$, as well as their mean, $\frac{T_1 + T_2 + T_3 + T_4}{4}$ (observations during which the instrument is reversed), are unaffected by collimation error. Hence, from the same series of observations (thus eliminating uncertainties arising from differences of seeing or other variations of conditions) we can obtain the required comparison of simple and reversed observations, as well as of the advantage gained by increasing the number of observations in each position of the instrument. The computations were made in the following way: In the first place, the mean of the four observations on each star was taken as the time of transit of that star; after applying corrections for level, pivot inequalities, &c., the observations were combined by least squares in the usual way for azimuth and clock error. The residuals were formed and examined for progressive change, denoting change of azimuth during the night; the most probable value of the rate of change (assumed constant) was computed by least squares, and applied as a correction to the original azimuth. This quantity (now a function of the time) was adopted as the definitive azimuth for the

night, and the residuals were reformed (see column v_1, Tables V, VI and VII). Next, the observations were grouped in the sense $\frac{T_1+T_4}{2}$, $\frac{T_2+T_3}{2}$, and these quantities were considered as distinct observations. The residuals were formed as before, using the same value of azimuth (column v_2). Finally, the observations were grouped in the sense $\frac{T_1+T_2}{2}$, $\frac{T_3+T_4}{2}$. In this case there are two values of collimation, the one to be used for any particular star depending on the direction of motion of the star and on the position of the instrument at the beginning of the observation—that is, on the particular half of the screw used for the observation of that star. A preliminary collimation correction of $25^s{\cdot}850$ sec. δ was applied to all the observations; here the exact value of δ for the particular day in question was required, since the coefficient of sec. δ was large; when the collimation is small an approximate value is sufficient. In the case of only one or two stars was a correction for curvature of path required; in those cases it was incorporated in the preliminary collimation correction. It was necessary also to apply the separate values of pivot inequality for Clamp West and Clamp East. It may be mentioned here that, the pivots of Cooke Transit No. 1 being somewhat irregular, a special series of observations was conducted to determine the irregularities at different zenith distances; a curve was plotted and the proper correction applied throughout to each star, depending on its zenith distance. After the preliminary collimation correction and the azimuth and clock corrections had been applied, the resulting equations were solved for the two values of collimation and the residuals were formed. As in the case of azimuth, the rate of change of collimation was computed from the residuals and applied; the residuals were then reformed (column v_3).

The results of this computation are shown in Tables V, VI and VII. The quantities denoted by the symbols are as follows:—

$$l_1 = a - \frac{T_1+T_2+T_3+T_4}{4} - Bb - {\cdot}01 \text{ sec. } \delta - \Delta T - \text{aberration.}$$

$$l_2 = a - \frac{T_1+T_4}{2} - Bb - {\cdot}01 \text{ sec. } \delta - \Delta T - \text{aberration.}$$

$$\text{and } a - \frac{T_2+T_3}{2} - Bb - {\cdot}01 \text{ sec. } \delta - \Delta T - \text{aberration.}$$

$$l_3 = a - \frac{T_1+T_2}{2} \mp 25{\cdot}850 \text{ sec. } \delta - Bb' - {\cdot}01 \text{ sec. } \delta - \Delta T - \text{aberration.}$$

$$\text{and } a - \frac{T_3+T_4}{2} \pm 25{\cdot}850 \text{ sec. } \delta - Bb' - {\cdot}01 \text{ sec. } \delta - \Delta T - \text{aberration.}$$

$v_1 = l_1 - Aa$
$v_2 = l_2 - Aa$
$v_3 = l_3 - Aa - Cc$
$A = \sin \overline{\phi - \delta}$ sec. δ
$B = \cos \overline{\phi - \delta}$ sec. δ
$C = \pm$ sec. δ
ΔT = clock correction.
a = azimuth error.
b = level error.
c = collimation error.

$\mu^2 = \frac{[v^2]}{n-\nu}$ = square of 'mean square' error of a single observation. The correction ·01 sec. δ is for the width of the contact strips on the micrometer head; the chronograph is actuated as soon as the edge of the brush touches the edge of the contact strip, that is, slightly before the position of symmetry is reached; the result

is a collimation effect, which, however, does not change sign when the instrument is reversed.

If μ_1, μ_2, μ_3 represent the mean square errors corresponding to the sets of residuals v_1, v_2, v_3, and if p_1, p_2, p_3 denote respectively the weights of a simple observation, an observation by reversal, and an observation combined from four simple observations as above, we have evidently $\frac{p_2}{p_1} = \frac{\mu_2^2}{\mu_1^2}$, $\frac{p_3}{p_2} = \frac{\mu_2^2}{\mu_1^2}$; these ratios are measures respectively of the advantage to be gained by simple reversal and of the additional advantage to be gained by doubling the number of observations in each position of the instrument. The values of μ_1^2, μ_2^2, &c., with their means, are collected in Table VIII. The weight of an observation is increased by two-thirds by reversal, while the additional advantage gained by increasing observations in the same position is only 16 per cent. We may conclude that the principle of reversal is well worth adopting, but that in general one observation in each position of the instrument is sufficient. For October 15 the values of $\frac{p_2}{p_1}$ and $\frac{p_3}{p_2}$ are considerably larger than for the other dates; as the weather on that night was hazy and the seeing poor this may be taken as an indication that under such conditions it might be worth while to take the full four observations if convenient.

The above values apply strictly, of course, only to stars of about the declination considered (about 70° to 80°); we might expect, however, that reversal would be of about equal benefit for all stars. We may test this hypothesis, though in a less rigorous way, by examining the mean square error shown for south stars during the observations in October, and comparing it with that shown in observations taken in the ordinary way. From the nineteen sets taken during that time the average value of μ^2 is ·00187; the separate values vary very considerably, as is to be expected from the small number of stars in a set (usually six to eight); the average value of the same quantity during the observations in December, 1906, and January, 1907, (practically the only other observations made by the writer with the transit micrometer) is ·00324. The ratio of these two quantities, corresponding to $\frac{p_2}{p_1}$, is 1·73, practically the same value as obtained above for polar stars. We may take it, then, as established that there is a gain of roughly two-thirds for all stars in making observations by reversal, and there will be a corresponding gain in the accuracy of the azimuth determination.*

It may be of interest now to inquire into the proper theoretical grouping of the component stars of a set, to see what influence changes in the grouping will have on the magnitude of errors. From each simple observation we obtain an observation equation of the form

$$C\ c + A\ a + \Delta T = l$$

where l is the clock error uncorrected for azimuth and collimation. Combining the observation equations we get the three normal equations

$$\left.\begin{aligned} [p\,C^2]\cdot c + [p\,A\,C]\cdot a + [p\,C]\cdot \Delta T &= [p\,C\,l] \\ [p\,A\,C]\cdot c + [p\,A^2]\cdot a + [p\,A]\cdot \Delta T &= [p\,A\,l] \\ [p\,C]\cdot c + [p\,A]\cdot a + [p]\cdot \Delta T &= [p\,l] \end{aligned}\right\}\quad\ldots\ldots\ldots\ldots(1)$$

where p is the weight of any observation equation (p being considered unity for an equatorial star). So far as the value of $\Delta\,T$ is concerned, these reduce to

*The method of observation by reversal has been practised for some years by the Prussian Geodetic Institute.

$$W . \triangle T = L \ldots\ldots (2)$$

$$\text{where } W = [p] - \frac{[p\,C]^2}{[p\,C^2]} - \frac{\left([p\,A] - \frac{[p\,A\,C]\;[p\,C]}{[p\,C^2]}\right)^2}{[p\,A^2] - \frac{[p\,A\,C]^2}{[p\,C^2]}} \ldots\ldots (3)$$

$$L = [p\,l] - \frac{[p\,C]\;[p\,C\,l]}{[p\,C^2]} - \frac{\left([p\,A] - \frac{[p\,A\,C]\;[p\,C]}{[p\,C^2]}\right)\left([p\,A\,l] - \frac{[p\,A\,C]\;[p\,C\,l]}{[p\,C^2]}\right)}{[P\,A^2] - \frac{[p\,A\,C]^2}{[p\,C^2]}} \quad (4)$$

If r_0 be the probable error of an observation on an equatorial star, and r_L that of L, it may be shown that $r_L = \sqrt{W} \cdot r_0$.*

$$\text{Hence } r_{\triangle T} = \frac{1}{\sqrt{W}} \cdot r_0 \ldots\ldots (5)$$

that is, W is the weight of the computed clock correction. The problem then reduces to that of finding the distribution of stars which will make W a maximum.

If, without altering the values of $[p]$, $[p\,A]$ and $[p\,A^2]$, we can make $[p\,C] = o$ and $[p\,A\,C] = o$, the value of W will be increased. For in (3), $[p]$ will be unaltered, while

$$\frac{[p\,C]^2}{[p\,C^2]} + \frac{\left([p\,A] - \frac{[p\,A\,C]\;[p\,C]}{[p\,C^2]}\right)^2}{[p\,A^2] - \frac{[p\,A\,C]^2}{[p\,C^2]}} \text{ will reduce to } \frac{[p\,A]^2}{[p\,A^2]},$$

which is a smaller quantity, as may be shown by direct subtraction, remembering that $[p\,A^2] - \frac{[p\,A\,C]^2}{[p\,C^2]}$ is positive, which may be easily proved.

In order to prove that it is always possible to satisfy this 'collimation condition' without altering the values of $[p]$, $[p\,A]$ and $[p\,A^2]$, it becomes necessary to make some assumption as to the relation between p and the declination. Assuming that the accidental error of an observation arises from two independent sources, one being the error of setting on a motionless star, the other that due to the star's motion, and proportional to its velocity, we shall have, if r is the probable error in time

$$r^2 = (m_1^2 + m_2^2 \cos^2 \delta) \sec^2 \delta = (1 + a^2 \tan^2 \delta)\, r_0^2 \ldots\ldots (6)$$

If p be taken as unity for an equatorial star, this gives

$$p = \frac{1}{1 + a^2 \tan^2 \delta} \ldots\ldots (7)$$

Since $A = \sin \phi - \cos \phi \tan \delta$, we have

$$[p\,A] = \sin \phi\,[p] - \cos \phi\,[p \tan \delta] \ldots\ldots (8)$$
$$[p\,A^2] = \sin^2 \phi\,[p] - 2 \sin \phi \cos \phi\,[p \tan \delta] + \cos^2 \phi\,[p \tan^2 \delta]$$

or, from (7) and (8)

$$[p\,A^2] = 2 \sin \phi\,[p\,A] + \frac{\cos^2 \phi}{a^2\,P}\,(n\,P - [p]) \ldots\ldots (9)$$

where n is the number of stars, and P the value of p for a zenith star. Hence if $[p]$ and $[p\,A]$ are constant, $[p\,A^2]$ is also constant.

Now for any combination of four stars, we may fulfil the collimation condition by pairing them, the stars in either pair being of the same declination, but in opposite clamps. In order that $[p]$ and $[p\,A]$, and, therefore, $[p\,A^2]$, may remain unchanged, we must also have, if δ_x and δ_y be the new declinations,

$$p_x + p_y = \tfrac{1}{2}\,[p]$$
$$p_x\,A_x + p_y\,A_y = \tfrac{1}{2}\,[p\,A]$$

* See Johnson—Theory of Errors and Method of Least Squares.

or, transforming with the help of (7) and (8)

$$\left.\begin{aligned} p_x \quad + \quad p_y \quad &= \tfrac{1}{2}\,[p] \\ \sqrt{p_x - p_x^2} + \sqrt{p_y - p_y^2} &= \frac{a}{2}\,[p \tan \delta] \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

The necessary condition that such a re-arrangement is possible, is that the values of p_x and p_y obtained from (10) shall be real and positive. It is fulfilled provided

$$4\,[p] > [p]^2 + a^2\,[p \tan \delta]^2,$$

the truth of which follows from the fact that

$$[p] = [p^2\,(1 + a^2 \tan^2 \delta)] = [p^2] + a^2\,[p^2 \tan^2 \delta]$$

and the general principle that

$$n\,(a_1^2 + a_2^2 + \ldots\ldots + a_n^2) > (a_1 + a_2 + \ldots\ldots + a_n)^2.$$

By repeating the above operation with the remaining stars, four at a time (using, if necessary, one of the pairs a second time to complete the last group of four), we arrive at the result that for any set containing an even number of stars, whatever the original distribution, we may so change that distribution as to make $[p\,C] = o$ and $[p\,A\,C] = o$, without altering $[p]$, $[p\,A]$ or $[p\,A^2]$. As has been shown above, this condition will increase the value of W. If it be fulfilled, (3) reduces to

$$W = [p] - \frac{[p\,A]^2}{[p\,A^2]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

If now we vary $[p\,A]$ and $[p\,A^2]$, subject to the condition that $[p]$ remain unchanged, it is evident that W is a maximum when $\dfrac{[p\,A]^2}{[p\,A^2]}$ is a minimum. Differentiating the latter quantity with respect to $[p\,A]$, and introducing (9), we obtain as the condition for a maximum

$$[p\,A]\left([p\,A] - \frac{\cos^2 \phi}{a^2\,P \sin \phi}\,[p] - n\,P\right) = o$$

that is,

$$[p\,A] = o \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

$$\text{or } [p\,A] = \frac{\cos^2 \phi}{a^2\,P \sin \phi}\,([p] - n\,P) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

according as $[p] \lesseqgtr n\,P$. This amounts to saying that $[p\,A]$ must be zero if consistent with the condition that $[p]$ remain unchanged; otherwise it must have the value given by (13). It may be remarked, in passing, that this is not its smallest possible value; the latter would involve $p_1 = p_2 = p_3 = \&c. > P$; that is, all the stars would be of the same declination, and all south of the zenith, a condition which, of course, would not be permissible.

If $[p] < n\,P$, (11) reduces to $W = [p]$, and now finally proceeding to vary $[p]$, yet still observing the condition (12), we may increase W by increasing $[p]$ up to the value $n\,P$. If $[p] > n\,P$, by applying (13), (9), and the relation $1 + a^2 \tan^2 \phi = \dfrac{1}{P}$, (11) becomes $W = (n - [p])\,\dfrac{P}{1 - P}$. Evidently in this case W increases as $[p]$ decreases till the latter reaches the value $n\,P$, in which case it is again equal to $n\,P$, while (13) now coincides with (12).

Hence, finally, the conditions for maximum efficiency are

$$\left.\begin{aligned} [p\,C] &= o \\ [p\,A\,C] &= o \\ [p\,A] &= o \\ [p] &= n\,P \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

They correspond to the case in which all stars are observed exactly in the zenith, an equal number in the two positions of the instrument.

Now this is a condition which it is obviously impossible to fulfil exactly in actual practice, and it becomes a question of experience whether, on account of the physical inconvenience of observing zenith stars, it can be even approximately fulfilled except

with a transit of the 'broken' type. Consequently, dismissing the collimation condition as indicating that the two 'clamps' should be roughly coincident, or, better still, that all observations should be made by reversal, it becomes of interest to inquire how much deviations from the other condition will affect the accuracy of the result. This is a problem which does not by any means yield readily to general treatment, but by imagining the set broken up into two groups, one north and the other south of the zenith, the stars of each group being all of the same declination, the problem is somewhat simplified. This will not involve any great departure from the actual conditions, since though the groups are usually spread over a considerable interval in declination, the distance between the groups is in general considerably greater.

If we have n south stars at declination δ and n' north stars at declination δ', and if we suppose the collimation condition to have been fulfilled, (11) will reduce to

$$W = \frac{n\,n'\,p\,p'\,(A - A')^2}{n\,p\,A^2 + n'\,p'\,A'^2} \quad \text{.......(15)}$$

Supposing the whole number of stars in the set, $n + n' = N$, to be fixed, and supposing δ and δ' also fixed, we may find the best distribution, i.e., the best values of n and n', by differentiating (15) with respect to n and n' and introducing the condition $dn + dn' = o$. This gives the condition

$$n^2\,p\,A^2 = n'^2\,p'\,A'^2 \quad \text{.......(16)}$$

Introducing this condition in (15) and eliminating n and n' we get

$$W = \frac{p\,p'\,(A - A')^2}{(\sqrt{p\,A^2} + \sqrt{p'\,A'^2})^2} \cdot N \quad \text{.......(17)}$$

the surd quantities being taken with the positive sign. This value of W is the maximum that can be obtained from N stars grouped at declinations δ and δ'. If now we differentiate (17) with respect to δ, and substitute the values of p, p', A and A' in terms of δ and δ', we get

$$\frac{1}{N} \cdot \frac{dW}{d\delta} = \frac{2\,p^2\,p'^2\,(A - A')}{(\sqrt{p\,A^2} + \sqrt{p'\,A'^2})^3} \left\{ \frac{(1 + a^2 \tan\delta \tan\delta')\,\sqrt{A'^2} +}{\sqrt{(1 + a^2 \tan^2\delta)\,(1 + a^2 \tan^2\delta')}} \cdot A' \right\} \frac{dA}{d\delta}$$

Now p, p' and A are positive, while $\frac{dA}{d\delta}$ is negative; also it may be easily shown that the quantity in the large brackets is of the same sign as A' (that is, negative when δ' is less than 90°, positive when greater). Hence $\frac{dW}{d\delta}$ is positive. In like manner, differentiating (17) with respect to δ', it may be shown that $\frac{dW}{d\delta'}$ is negative. Hence W is increased either by increasing δ or decreasing δ', that is, by diminishing the zenith distance of either north or south stars, or both, *provided the ratio* $\frac{n'}{n}$ *be at the same time so varied as to satisfy* (16). This conclusion includes the case of north stars at lower culmination.

The best set, then, can be obtained by the use of stars, both north and south, as near to the zenith as they can comfortably be observed. We have yet to consider, however, whether there are any practical considerations, such as the number of stars obtainable at different declinations, which will interfere with the adoption of this principle. To get a clearer idea of the amount of variation in precision corresponding to variations in declination, we may compute W and also n and n', for special values of δ and δ'. To do this we must, however, make an assumption as to the value of a^2 in (7), which can be obtained only by observation. It has been computed from the results of several years' observations by the Prussian Geodetic Institute,* com-

* See 'Test of a Transit Micrometer,' U. S. Coast and Geodetic Survey Report, 1904.

prising the work of several observers; the values for different years and for different observers vary from ·11 to ·44, the mean value being ·21. Some data from which its value may be computed are also given by a test of the transit-micrometer of the Meridian Circle at Munich;† the approximate value in this case is ·26. From some tests made by the United States Coast and Geodetic Survey, they came to the conclusion that 'the total error for a star . . . . . is nearly the same for stars of all declinations, if expressed in angular measure. This is what should be expected if the errors concerned are of the same nature as if the object pointed upon were stationary instead of being a moving star.'* This would correspond to the value unity for a^2.

It may be remarked that the value of a probably varies considerably with the instrumental conditions, such as speed of driving heads, magnifying power, definition of image, &c.

Regarding the first point the matter is put very well in the United States Coast and Geodetic Survey report* as follows: 'If the speed of the driving heads is made very great, the observer will have difficulty in making the moving line keep up with the moving star-image, and this difficulty will be greater for the fast-moving equatorial stars than for others. The errors of bisection expressed in angular measure should be considerably greater for equatorial stars than for slow-moving stars under these conditions. If the speed of the driving heads is made very small, there will be no difficulty in keeping up with any star. A given error in the position of the driving heads at any instant will produce, however, a much larger displacement of the movable line in the field of view than when the driving heads are geared to move much more rapidly. The consequent difficulty in placing the movable line in a desired position will tend to produce errors of bisection of about the same magnitude expressed in angular measure for all declinations, and the size of the errors will tend to increase as the speed of the driving heads is made slower.' These changes in conditions would correspond to a change in the value of a.

Again, in obtaining the formula for p, no account was taken of the magnification employed. An increase in the magnification (up to certain limits) might be expected to diminish m_1 in (6), that is, to increase the accuracy of setting on a stationary point; on the other hand, the tendency would be for m_2, the error depending on the star's motion, to be relatively unaffected; for while from one cause it would tend to be reduced in the same ratio as m_1, the increase in magnification would increase the star's apparent velocity, and so by hypothesis increase m_2; these two tendencies would more or less balance each other, and we should have m_2 nearly constant, while m_1 would vary inversely as the magnification. As $a^2 = \dfrac{m_1^2}{m_1^2 + m_2^2}$, a would decrease with increase of magnification.

From these considerations it would seem best to adopt for the present purpose the value of a given by observations with the same type of instrument which we are considering, namely, the Cooke transit. From the values of μ_2^2 given in Table VIII, together with the value $\mu^2 = \cdot 00187$ for stars about declination 22°, we obtain for a^2 the values ·56, ·44 and ·40, the mean being ·47, or roughly one-half. This value has been used in the computations below. We, of course, have no definite proof that the variations of p follow the law we have assumed (that is, that a is constant for all declinations), but at least this assumption can not lead us far astray if the declinations we consider do not depart too far from those from which our value of a was deduced.

In Table IX are shown the maximum weights, as computed from (17), of sets of twelve stars observed at the latitude of Ottawa (45° 24′), for different values of δ and δ'; also the values of n' as computed from (16). The unit of weight has in this case been taken as an observation on a single zenith star. The values for 90°

† Astronomische Nachrichten, No. 3942-3, Band 165.

* See 'Test of a Transit Micrometer,' U.S. Coast and Geodetic Survey Report, 1904.

have been added simply to show the tendency as δ' is increased beyond 80°. The desideratum is to so choose δ and δ' that the value of W may be as high as possible without unduly increasing n', since stars are relatively much scarcer north than south of the zenith. By increasing δ, n' is markedly decreased, while W is increased; hence for both reasons, but more especially the former, the south stars should be observed as near the zenith as practicable. It is probably unwise to observe any stars of less zenith distance than seven or eight degrees, because the free use of the micrometer heads is interfered with by the standards of the telescope. In actual practice, in order to get a sufficient number of stars in a reasonable time, this will involve a mean value of zenith distance not less than 20°. In the case of north stars (see Table IX) a decrease in δ', while it increases W, also increases n' in a much greater ratio; on the other hand, the number of stars available in the Berliner Jahrbuch is about the same between declinations 70° and 80° as between 60° and 70°. Hence, instead of choosing 65° (a zenith distance of 20°) as the mean declination of polars, it will be better to choose 75°, as this will not involve a great decrease in W, while it will permit us to observe nearly the proper ratio of polars in the set. For $\delta = 25°$ and $\delta' = 75°$ we get $n' = 4{\cdot}2$; that is, the best results for these declinations are got by observing in the ratio of about one north star to two south stars, instead of one to five or six as has been usually done. We might still further lower n' without very materially decreasing W by increasing δ' beyond 75°, but, in addition to the fact that the difficulties of observing with the micrometer are greatly increased for stars much beyond 80° declination, the number of stars available decreases more rapidly than n'; consequently, the best declination for polars is probably from 70° to 82° or 83°.

Tables X and XI show the weights, computed by formula (15), of sets of twelve stars for the same declinations as above, the numbers of polars being respectively two and four. An inspection of the corresponding weights in both tables shows that the advantage gained by increasing the number of polars is very considerable.

Tables XII, XIII and XIV are the same as the three preceding ones, except that they are computed for latitude 35°. Tables XV, XVI and XVII are computed for latitude 55°. The similarity in the weights (for equal zenith distances) in all three sets of tables shows that the same general conclusions hold also for those latitudes and for intermediate ones.

In Table XVIII are collected the weights for a few typical sets, showing the advantages to be gained by decreasing the zenith distance of the south stars, by increasing the relative number of polars, and by reversing during each observation. In the case of the sets observed by reversal the weights obtained by formula (15) have been increased by two-thirds, in accordance with the results arrived at above. In all cases the weights given by the formula have been multiplied by $(1 + a^2 \tan^2 \phi)$, in order to make the unit a zenith star.

It is, of course, to be remembered that in all that precedes, the only errors taken account of have been those inherent in the actual observation; it has been tacitly assumed, for instance, that the adopted correction for level, as applied to any one set taken as a whole, does not differ appreciably from its true value, that the collimation of the instrument does not change with variations in position, that anomalous changes in refraction do not affect the result, that the residual pivot errors are negligible, &c. Though none of these assumptions is strictly true, the actual evidence shows that these errors are overbalanced by the errors arising from defective azimuth determinations, i.e., by relatively insufficient observations of northern stars; consequently, the introduction of the consideration of relatively insignificant errors would tend to alter merely the relative and absolute *values* of the theoretical weights, but not their *sequence*. We must not expect, then, to gain the whole advantage shown by the differences in the weights in Table XVIII, but of some advantage, and probably a very considerable one, we may be assured.

There is a method of taking time observations which has not been considered. We might obtain a strong azimuth determination by observing north stars, some at upper and some at lower culmination; this value of the azimuth applied to the south stars would give the clock error. In some observations taken to test this method there was, however, an indication of a systematic difference between azimuths so determined and those derived from a combination of north and south stars. Even if this were the case, it would make little difference, provided the same method were always adhered to; however, in a set containing polars at upper and at lower culmination it is necessary to observe in three distinct parts of the sky, and to any one who has struggled with clouds on a broken night it will be readily apparent that this might not always be feasible.

There is still another matter to be considered. We have considered as mutually exclusive the two alternatives of observing polars between declinations 60° and 70°, or between 70° and 80°. We might, however, distribute the polars between 60° and 80°; this would involve (for the best results) an additional increase in the number of polars observed, but this would be more than compensated for (so far as scarcity of polars is concerned) by the additional number available. In making the computations it has always been the custom here to give all observations equal weights, and so far as the value of $\triangle T$ is concerned this is perfectly legitimate, *provided the polars are not spread over a wide range of declination;* if this condition is fulfilled the value obtained for $\triangle T$ will be practically the same whatever system of weights be employed, but if not, we can not get a correct result without weighting the observations for different declinations. Whether the advantage to be gained by opening a wider range of declination for polars is more than sufficient to compensate for the increased labour of computation involved by weighting the observations, is a matter to be decided by experience. The question is whether under actual working conditions it will be possible always to obtain a sufficient percentage of stars between 70° and 80°; if not we may have recourse to the other expedient.

So far as concerns actual results of observation, on which to base an estimate of the improvement attainable, they are as yet naturally rather meagre. No time has been available for a test along these lines, further than that furnished by the regular observations, nor was it considered advisable to make special observations for that purpose, as a thorough test will be available from the longitude work during the coming summer. Enough knowledge has been gained, however, to show that the method of observation is perfectly feasible, and so far as the possibility of a comparison goes, the improvement in accuracy seems decided. On nine nights during October last, two time sets were taken in connection with the longitude work then in progress. The average discordance between two sets on the same night was ·019 sec.; the largest being ·042 sec.; the average discordance obtained previously (as mentioned above) was just double this. Theoretically these quantities should be proportional to the probable errors; it is hardly likely, however, that the average from a larger number of nights would be so small as ·019 sec., since this would mean a four-fold increase in the weight of a set.

Contrary to what might be expected, there is very little additional labour involved in the observation of a set by the new method. The scaling is considerably increased, but the computation is very much simplified; even if a system of weighting should have to be adopted the computation would still be on the whole rather simpler. It may be added that the observers here are all in accordance with the writer as to the necessity for an improvement in the methods of observation, and as to the efficiency of the remedy proposed.

Conclusions.

A time set should consist of a certain number of south stars, combined with a suitable number of polars at upper culmination (except in high latitudes, when it would be necessary to use stars culminating below the pole, which should be at

declinations as high as feasible). The south stars should be selected as near the zenith as they can comfortably be observed; the north stars, provided a suitable number can be obtained, should lie between declinations 70° and 82° or 83°; otherwise the southern limit may be extended to perhaps 60°.

The distribution of north and south stars, provided the north stars be above 70°, should be roughly one north star to two south stars; if north stars be observed at lower declinations their number should be increased. This is on the assumption that the mean zenith distance of the south stars is about 20°. If the instrument used is such that this zenith distance can be materially lessened the above ratio of north stars may be somewhat decreased; an approximation to its value can be obtained from Table IX.

The instrument should be reversed during the observation of all stars.

When the declinations of the polars are above 70°, it is permissible in the computation to give all observations equal weight; if, however, the north stars are spread over a greater interval in declination, it will be necessary to weight the observations according to the declinations.

TABLE IV. REDUCTION BY SEPARATE AND BY MEAN AZIMUTHS.

Date.	ΔT	Discordance.	ΔT	Discordance.
	s		s	
Aug. 17, 1905....	3·589 3·486	103	3·527 3·480	047
Aug. 25, 1905 ...	3·501 3·403 3·437	098	3·478 3·429 3·425	·053
Sept. 8, 1905....	3·433 3·352	081	3·405 3·376	029
Apr. 2, 1906	—14·217 —14·109	108	—14·183 -14·156	027
June 19, 1906 ..	-28·571 -28·654	·083	—28·591 —28·628	037
July 6, 1906	— 0·240 — 0·353	·113	— 0·298 — 0·314	016
July 9, 1906.......	— 0·471 — 0·567	·096	— 0·512 — 0·526	014
July 19, 1906	— 1·228 — 1·329	·101	— 1·254 — 1·268	·014
Dec. 17, 1906 ...	— 2·704 — 2·601	103	— 2·635 — 2·659	024
Dec. 19, 1906 ...	— 3·182 — 3·053	129	— 3·154 — 3·077	·077
Mean	....	·102	....	·034

TABLE V.—TRANSIT OBSERVATIONS, OCTOBER 8, 1907.

Star.	α		δ		l_1	l_2	l_3	Aa	Cc	v_1	v_2	v_3
	h.	m.	°	'								
502*	20	12	77	26	1·40	1·37	2·46	1·31	·93	·09	·06	·22
						1·43	·35	1·31	—·93		·12	—·03
510*	21	07	77	45	1·43	1·39	2·30	1·34	·96	09	·05	·00
						1·47	·55	1·34	—·96		·13	·17
516	21	41	70	53	·63	·55	—·03	·69	—·74	·06	—·14	·02
						·71	1·29	·69	·74		·02	—·14
521	22	08	71	53	·71	·74	·07	·75	—80	—·04	—·01	12
						·68	1·36	·75	·80		—·07	—·19
525*	22	34	73	10	·87	·89	1·69	·84	·73	03	·05	·12
						·85	·06	·84	—·73		·01	—·05
529	23	05	74	53	1·23	1·18	·08	·98	—·96	·25	·20	·06
						1·28	2·38	98	·96		·30	44
334	23	36	77	07	1·46	1·50	·43	1·21	—1·13	25	·29	·35
						1·42	2·50	1·21	1·13		·21	·16
440*	12	00	77	25	—1·87	—1·88	—·99	—1·98	1·00	·11	10	—·01
						—1·86	—2·75	—1·98	—1·00		·12	·23
338*	0	11	76	26	·96	·97	1·99	1·13	·92	—·17	—16	—·06
						·95	—·07	1·13	—92		—·18	—·28
171	12	29	70	18	—1·32	—1·28	—2·04	—1·36	—·76	·04	·08	·08
						—1·36	·61	—1·36	·76		·00	·01
340	0	40	74	29	·72	·68	—·26	·92	—·96	—·20	—·24	—·22
						·76	1·70	92	·96		—·16	—·18
345	1	04	79	11	1·41	1·41	·03	1·49	1·38	08	—·08	—·08
						1·41	2·80	1·49	1·38		—·08	—·07
452	13	24	72	52	—1·52	—1·53	—2·38	—1·50	—·88	—·02	—·03	·00
						—1·51	—·67	—1·50	·88		—·01	—·05
347	1	31	72	34	·70	·68	—·27	·76	—·87	—·06	—·08	—16
						·72	1·67	·76	·87		—·04	·04
31*	1	56	71	58	·69	·66	1·52	·72	·73	—·03	—·06	·07
						·72	—·14	·72	—·73		·00	—·13
459*	14	09	77	59	—1·96	—1·89	—·92	—1·99	1·08	·03	·10	—01
						—2·03	—3·00	—1·99	—1·08		—·04	·07
38	2	29	72	25	·87	·92	—·02	·74	—·87	·13	18	·11
						·82	1·75	·74	·87		·08	·14
198	14	51	74	32	—1·76	—1·83	—2·64	—1·61	—·99	—·15	—·22	—·04
						—1·69	—·88	—1·61	·99		—·08	—·26
360	3	09	77	24	1·16	1·19	—·11	1·19	—1·22	—·03	·00	—·08
						1·13	2·43	1·19	1·22		—·06	·02
203	15	21	72	10	—1·48	—1·48	—2·40	—1·42	—·87	—·06	—·06	—·11
						—1·48	—·56	—1·42	·87		—·06	—·01
472*	16	13	76	07	—1·70	—1·72	—·77	—1·72	·97	·02	·00	—·02
						—1·68	—2·63	—1·72	—·97		·04	·06
474	16	20	75	58	—1·75	—1·80	—2·83	—1·70	—1·12	—·05	—·10	—·01
						—1·70	—·67	—1·70	1·12		·00	—·09
$[v^2]$	......		......		......	......	......	......	......	·2889	·6626	·9855
μ^2	....		......		......	......	......	......	......	·0144	·0158	·0246

$a = -·508^s + ·00623\ (T - 0·7^h).$
$c = -·219^s - 00392\ (T - 0·7^h)$ for stars marked (*).
$c = -·257^s - ·00392\ (T - 0·7^h)$ for other stars.

TABLE VI.—TRANSIT OBSERVATIONS, OCT. 15, 1907.

Star.	α		δ		t_1	t_2	t_3	Aa	Cc	v_1	v_2	v_3
	h.	m.	°	′								
510	21	07	77	45	1·46	1·42	·59	1·39	— ·94	·07	·03	·14
						1·50	2·33	1·39	·94		11	·00
308	21	28	70	10	·73	·67	08	·67	—·60	·06	00	01
						·79	1·39	·67	60		12	12
516	21	41	70	53	·70	·64	01	·71	— ·62	— 01	·07	—·08
						·76	1·38	·71	62		05	05
521*	22	08	71	53	·74	·77	1·40	·75	·60	— 01	02	·05
						·71	·09	·75	·60		—·04	— 06
525*	22	34	73	10	·86	·78	1·51	·84	·65	·02	—·06	02
						·94	·21	·84	·65		·10	02
529*	23	05	74	53	1·12	1·11	1·84	·97	·72	·15	14	15
						1·13	·40	·97	—·72		·16	·15
334*	23	36	77	07	1·27	1·30	2·15	1·19	·85	·08	·11	·11
						1·24	·40	1·19	·85		·05	06
440	12	00	77	25	—2·00	—2·00	—2·84	1·91	—·95	09	09	·02
						—2·00	—1·16	—1·91	95		—·09	20
171*	12	29	70	18	—1·37	—1·37	—·94	—1·30	·56	—·07	07	— 20
						—1·37	1·81	1·30	·56		— 07	05
340*	0	40	74	29	·93	·96	1·71	·89	·71	04	07	·11
						·90	·15	·89	·71		·01	03
345*	1	04	79	11	1·61	1·69	2·66	1·41	1·02	·20	·28	23
						1·53	·55	1·41	1·02		12	16
452	13	24	72	52	—1·41	—1·47	—2·10	1·41	·71	·00	— 06	02
						1·35	—·72	—1·41	71		06	02
347	1	31	72	34	·67	·68	·12	·72	·70	—·05	— 04	·14
						·66	1·47	·72	·70		—·06	05
31*	1	56	71	58	·55	·54	1·26	·67	·62	—·12	—·13	— 03
						·56	—·16	·67	— ·62		— 11	— 21
459*	14	09	77	59	—1·97	—1·86	1·10	—1·84	·93	13	— 02	—·19
						—2·08	2·84	1·84	·93		— 24	07
38	2	29	72	25	·71	·71	—·07	·68	·70	03	03	05
						·71	1·49	·68	·70		03	11
198	14	51	74	32	1·78	1·79	2·49	1·46	— ·79	·32	— 33	24
						—1·77	1·06	—1·46	79		— 31	29
360*	3	09	77	24	1·05	1·05	2·11	1·07	·89	02	02	15
						1·05	—·01	1·07	·89		— 02	19
203*	15	21	72	10	—1·27	1·30	·75	—1·27	·64	·00	—·03	12
						1·24	1·80	—1·27	·64		03	11
364	3	41	71	03	·59	·60	—·15	·58	— ·65	01	02	— 08
						·58	1·34	·58	·65		00	11
217	15	47	78	05	—1·71	—1·69	—2·60	—1·74	—1·03	·03	05	17
						1·73	—·82	—1·74	1·03		01	—·11
472*	16	13	76	07	—1·50	—1·42	—·76	—1·50	·82	00	08	— 08
						—1·58	—2·24	—1·50	— ·82		—·08	08
474	16	20	75	58	—1·57	—1·57	—2·37	—1·48	— ·88	—·09	—·09	—·01
						—1·57	—·77	—1·48	·88		— 09	—·17
369	4	36	75	46	·86	·93	—·16	·86	·87	·00	·07	—·15
						·79	1·88	·86	·87		—·07	15
235	16	55	82	12	—2·35	—2·14	3·82	—2·44	—1·58	09	·30	20
						—2·56	—·88	—2·44	1·58		—·12	—·02
373	5	07	79	07	1·27	1·37	·02	1·21	—1·14	·06	16	—·05
						1·17	2·52	1·21	1·14		—·04	17
[v^2]										2509	7162	9214
u^2										0105	·0143	·0192

$a = ·471^s - ·01726\,(T - 1·5^h)$.
$c = - ·193^s - ·00175\,(T - 1·5^h)$ for stars marked (*).
$c = - ·209^s - ·00175\,(T - 1·5^h)$ for other stars.

TABLE VII.—TRANSIT OBSERVATIONS, OCT. 30, 1907.

Star.	α		δ		t_1	t_2	t_3	Aa	Cc	v_1	v_2	v_3
	h.	m.		′								
308*	21	27	70	10	2 66	2·62	1·83	2·71	—.84	—·05	—·09	— 04
						2·70	3·49	2·71	·84		— 01	—·06
516	21	41	70	53	2·90	2·94	3·79	2·89	·82	·01	·05	·08
						2·86	2·01	2·89	— ·82		—·03	—·06
521*	22	08	71	53	3·29	3·27	2·33	3·15	— 91	·14	·12	·09
						3·31	4·25	3·15	·91		·16	·19
525*	22	34	73	10	3·52	3·50	2·58	3·54	— ·98	—·02	—·04	02
						3·54	4·46	3·54	·98		·00	—·06
529	23	05	74	54	4·22	4·17	5·17	4·15	1·04	·07	·02	—·02
						4·27	3·28	4·15	—1·04		·12	·17
334*	23	36	77	07	5·44	5·48	4·20	5·18	—1·28	26	·30	·30
						5·40	6·68	5·18	1·28		·22	·22
338*	0	11	76	26	4·87	4·84	3·64	4·80	—1·23	·07	·04	·07
						4·90	6·11	4·80	1·23		·10	·08
171	12	29	70	18	—5·91	—5 96	—5·11	—5·82	·81	—·09	—·14	—·10
						—5·86	—6·72	—5·82	— 81		—·04	—·09
340	0	40	74	29	3·81	3·86	4·85	3 98	1·02	—·17	— 12	—·15
						3·76	2·78	3·98	—1·02		—·22	— 18
345*	1	04	79	11	6·52	6·47	5·06	6·47	—1·54	·05	·00	13
						6·57	7·98	6·47	1·54		·10	—·03
452	13	24	72	52	—6 53	—6·53	—5·58	—6·51	·94	—·02	— 02	—·01
						6·53	—7·48	—6·51	94		—·02	—·03
347	1	31	72	34	3·23	3·21	4·13	3·32	92	—·09	—·11	—·11
						3·25	2·33	3·32	·92		—·07	—·07
31*	1	56	71	58	3·13	3·15	2·35	3·16	—·94	·03	—·01	·13
						3·11	3·90	3·16	·94		—·05	—·20
459*	14	09	77	59	—8 89	—8·78	—10·20	—8·72	—1·39	—·08	—·06	—·09
						—8·82	—7·40	—8·72	1·39		—·10	— 07
38	2	29	72	25	3·36	3·39	4·23	3·26	·91	·10	·13	·06
						3·33	2·49	3·26	—·91		·07	·14
198	14	51	74	32	—7·14	—7·20	—6·02	—7·05	1·05	— 09	— 15	—·02
						—7·08	—8·27	—7·05	—1·05		—·03	—·17
360	3	09	77	24	5·21	5·17	6·37	5·28	1·27	—·07	— 11	—·18
						5·25	4·06	5·28	—1·27		— 03	·05
203	15	21	72	10	—6·31	—6·30	-5·37	—6·25	·91	—·06	— 05	03
						—6·32	—7·25	—6·25	— ·91		— 07	—·09
364*	3	41	71	03	2·95	2·91	2·15	2·89	— ·90	06	·02	·16
						2·99	3·75	2·89	·90		·10	—·04
217*	15	47	78	05	—8·84	—8·80	—10·39	—8·74	—1·41	— 10	—·06	—·24
						—8·88	—7·28	—8·74	1·41		— 14	·05
.472	16	13	76	07	—7·64	—7·66	—6·36	—7·67	1·17	·03	01	·14
						—7·62	—8·93	—7·67	—1·17		·05	—·09
474*	16	20	75	58	—7 65	—7·60	—8·95	—7·61	—1·21	—·04	·01	—·13
						—7·70	—6·34	—7·61	1·21		—·09	·06
369*	4	36	75	46	4·32	4 36	3·21	4·45	—1.20	—·13	—·09	—·04
						4·28	5·43	4·45	1·20		— 17	—·22
235*	16	55	82	12	—12·62	—12·69	—14·87	—12 81	—2·17	·19	·12	·11
						—12·55	—10·38	—12·81	2·17		·26	·26
373*	5	07	79	07	6·37	6·34	4·86	6·38	—1·57	—·01	—·04	·05
						6·40	7·88	6·38	1·57		·02	—·07
92*	5	27	74	59	4·31	4·34	3·19	4·13	—1·14	·18	21	·20
						4·28	5·43	4·13	1·14		·15	16
(v^2)	.....	.....	.....	.....	.....	.....	.....	.....	.....	·2835	·6436	·8557
μ^2	.....	.....	.....	.....	.....	.....	.....	.....	.....	·0118	·0129	·0178

$a = -2·182^s + ·00591\ (T-1·8^h)$
$c = ·290^s - ·00169\ (T-1·8^h)$ for stars marked (*).
$c = ·276^s - ·00169\ (T-1·8^h)$ for other stars.

TABLE VIII.—RELATIVE WEIGHTS OF SIMPLE AND REVERSED OBSERVATIONS.

Date.	μ_1^2	μ_2^2	μ_3^2	$\frac{p_2}{p_1}$	$\frac{p_3}{p_2}$
October 8	·0144	·0158	0246	1·71	1·10
October 15	·0105	·0143	·0192	1·83	1 36
October 30	·0118	·0129	·0178	1·51	1·09
Means	·0123	·0143	0205	1·67	1·16

TABLE IX.—MAXIMUM WEIGHTS OF SETS OF 12 STARS FOR LATITUDE 45° 24′

—	$\delta=0°$		$\delta=10°$		$\delta=20°$		$\delta=30°$	
	W	n	W	n'	W	n'	W	n'
$\delta'=60°$	10·1	8·3	10·5	7·8	10·9	7·0	11·3	5·7
$\delta'=70°$	8·8	6·7	9·4	6·1	10·0	5·3	10·7	4·1
$\delta'=80°$	7·5	5·7	8·2	5·1	9·1	4·3	10·1	3·2
$\delta'=90°$	6·2	5·0	7·1	4·4	8·2	3·7	9 4	2·7

TABLE X.—WEIGHTS OF SETS OF 10 SOUTH AND 2 NORTH STARS FOR LATITUDE 45° 24′

—	$\delta=0°$	$\delta=10°$	$\delta=20°$	$\delta=30°$
$\delta'=60°$	3·4	3·9	4·9	6·8
$\delta'=70°$	4·1	5·1	6·5	8·8
$\delta'=80°$	4·4	5·6	7·2	9 5
$\delta'=90°$	4·2	5·5	7·1	9·2

TABLE XI.—WEIGHTS OF SETS OF 8 SOUTH AND 4 NORTH STARS FOR LATITUDE 45° 24′

—	$\delta=0°$	$\delta=10°$	$\delta=20°$	$\delta=30°$
$\delta'=60°$	6·4	7·3	8·5	10·4
$\delta'=70°$	7·1	8 2	9·5	10·7
$\delta'=80°$	6·9	8·0	9·1	9·9
$\delta'=90°$	6·0	7·1	8·1	8·9

TABLE XII.—MAXIMUM WEIGHTS OF SETS OF 12 STARS FOR LATITUDE 35°

—	$\delta=-10°$		$\delta=0°$		$\delta=10°$		$\delta=20°$	
	W	n'	W	n'	W	n'	W	n'
$\delta'=50°$	10·4	8·5	10·7	7·8	11·1	7·0	11·4	5·6
$\delta'=60°$	9·2	6·8	9·8	6·2	10·4	5·3	11·0	4·0
$\delta'=70°$	8·1	5·8	8·8	5·1	9·6	4·3	10·5	3·1
$\delta'=80°$	6·9	5·0	7·8	4·4	8·8	3·6	9·9	2·6

TABLE XIII.—WEIGHTS OF SETS OF 10 SOUTH AND 2 NORTH STARS FOR LATITUDE 35°

—	$\delta=-10°$	$\delta=0°$	$\delta=10°$	$\delta=20°$
$\delta'=50°$	3·4	4·0	5·0	7·0
$\delta'=60°$	4·3	5·2	6·7	9·2
$\delta'=70°$	4·7	6·0	7·6	9·9
$\delta'=80°$	4·7	6·0	7·7	9·7

TABLE XIV.—WEIGHTS OF SETS OF 8 SOUTH AND 4 NORTH STARS FOR LATITUDE 35°

—	$\delta=-10°$	$\delta=0°$	$\delta=10°$	$\delta=20°$
$\delta'=50°$	6·5	7·4	8·7	10·6
$\delta'=60°$	7·4	8·6	9·8	11·0
$\delta'=70°$	7·3	8·5	9·6	10·2
$\delta'=80°$	6·6	7·7	8·7	9·3

TABLE XV.—MAXIMUM WEIGHTS OF SETS OF 12 STARS FOR LATITUDE 55°.

—	$\delta = 10°$		$\delta = 20°$		$\delta = 30°$		$\delta = 40°$	
	W	n'	W	n'	W	n'	W	n'
$\delta' = 70°$	9·7	8·1	10·1	7·6	10·6	6·8	11·1	5·5
$\delta' = 80°$	8·2	6·6	8·9	6·0	9·6	5·2	10 4	4·0
$\delta' = 90°$	6·8	5·6	7·6	5 1	8·6	4·3	9·7	3·2

TABLE XVI.—WEIGHTS OF SETS OF 10 SOUTH AND 2 NORTH STARS FOR LATITUDE 55°.

—	$\delta = 10°$	$\delta = 20°$	$\delta = 30°$	$\delta = 40°$
$\delta' = 70°$	3 4	4·0	4·9	6·9
$\delta' = 80°$	4 0	4·9	6·3	8·7
$\delta' = 90°$	4·1	5·2	6·8	9·1

TABLE XVII.—WEIGHTS OF SETS OF 8 SOUTH AND 4 NORTH STARS FOR LATITUDE 55°.

—	$\delta = 10°$	$\delta = 20°$	$\delta = 30°$	$\delta = 40°$
$\delta' = 70°$	6·4	7·3	8·5	10·4
$\delta' = 80°$	6·7	7·9	9·2	10·4
$\delta' = 90°$	6·3	7·4	8·5	9·5

TABLE XVIII.—COMPARATIVE WEIGHTS OF TIME SETS.

No. of polars.	δ'	No. of south stars.	δ	Method of observation.	Weight.
*2	76° 45′	10	14°	Without reversal	6·0
†2	78° 19′	10	14°	" "	6·1
‡2	83° 30′	10	14°	" "	6·2
2	75°	10	25°	" "	8·0
2	"	12	"	" "	8·6
2	"	4	"	By reversal..............	8·3
2	"	6	"	" "	10·5
3	"	6	"	" "	12·5
3	"	8	"	" "	14·8
4	"	8	"	" "	16·6

* Values of δ and δ' actual means from a large number of sets observed in the past.

† Condition $[A]=0$ fulfilled.

‡ If $\delta=14°$, $n=10$, $n'=2$, W is a maximum when $\delta'=83° \ 30'$

I have the honour to be, sir,
Your obedient servant,

R. M. STEWART.

APPENDIX 4.

REPORT OF THE CHIEF ASTRONOMER, 1908.

TABULAR STATEMENT OF LONGITUDE AND LATITUDE OBSERVATIONS, 1907

BY

J. MACARA.

CONTENTS.

MAP.

APPENDIX 4.

TABULAR STATEMENT OF LONGITUDE AND LATITUDE OBSERVATIONS.

Department of the Interior,
Dominion Astronomical Observatory,
Ottawa, Canada, March 31, 1908.

W. F. King, Esq., B.A., LL.D.,
Chief Astronomer,
Ottawa.

Sir,—I have the honour to transmit herewith a tabular statement of the differences of longitude and the latitude results of stations observed in 1907. Annexed thereto is, also, a description of the stations occupied. A synopsis of the statement giving the longitude and latitude of the various stations will be found on page 322.

The accompanying map shows the position of the various astronomical stations established up to the date of this report.

I have the honour to be, sir,
Your obedient servant,

J. MACARA.

DIFFERENCE OF LONGITUDE BETWEEN DAWSON AND BOUNDARY.

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.	r.	
1907.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.		
June 13	7 10·023	7 10·044	+3 12·208	+2 18·279	6 16·094	6 16·115	6 16·105		
" 16	20·552	20·560	3 20·015	+2 15·680	16·217	16·225	16·221		
" 20	42·680	42·676	3 31·862	+2 05·323	16·141	16·137	16·139		
" 25	8 02·172	8 02·191	3 44·196	+1 58·130	16·106	16·125	16·115		
" 26	04·416	04·439	+3 47·071	+1 58·721	16·066	16·089	16·078		
" 28	06·737	06·783	3 51·121	+2 00·491	16·107	16·153	16·130		

Observers: { West—W. C. Jaques.
{ East—F. A. McDiarmid.

	h.	m.	s.
Mean		6	16·131
Longitude of Boundary	9	24	00·027
" Dawson	9	17	43·896

DIFFERENCE OF LONGITUDE BETWEEN SELKIRK AND DAWSON.

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.		
1907.	m. s.	m. s.	s.	s.	m. s.	m. s.	m. s.		
July 5	8 58·467	8 58·537	+ 9·261	−35·953	8 13·253	8 13·323	8 13·288		
" 7	9 10·513	9 10·583	+14·854	−42·418	13·241	13·311	13·276		
" 11	9 27·740	9 27·785	+22·327	52·055	13·358	13·393	13·375		
" 13	9 34·654	9 34·680	+24·119	57·256	13·279	13·305	13·292		
" 14	9 39·922	9 39·938	+27·479	59·214	13·229	13·245	13·237		

Observers: { West—W. C. Jaques.
East—F. A. McDiarmid.

	h. m. s.
Mean	8 13·294
Longitude of Dawson	9 17 43·896
" Selkirk	9 09 30·602

DIFFERENCE OF LONGITUDE BETWEEN TANTALUS AND DAWSON.

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.	e.	
1907.	m. s.	m. s.	s.	m. s.	m. s.	m. s.	m. s.		
July 18	16 21·114	16 21·150	+38·838	−3 07·011	12 35·265	12 35·301	12 35·283		
" 20	23·457	23·481	+41·083	−3 07·050	35·324	35·348	35·336		
" 22	23·496	23·514	+43·809	−3 04·402	35·285	35·303	35·294		
" 23	21·785	21·821	+43·613	−3 02·889	35·283	35·319	35·301		
" 24	21·432	21·469	+44·291	−3 01·807	35·334	35·371	35·352		

Observers: { West—W. C. Jaques.
{ East—F. A. McDiarmid.

	h.	m.	s.
Mean		12	35·313
Longitude of Dawson	9	17	43·896
" Tantalus	9	05	08·583

DIFFERENCE OF LONGITUDE BETWEEN WHITEHORSE AND DAWSON.

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.	r	
1907.	m. s.	m. s.	m. s.	s.	m. s.	m. s.	m. s.		
July 29	19 21·000	19 21·056	+59·823	−48·854	17 32·323	17 32·379	17 32·351	....	....
" 30	22·312	22·357	1 02·269	−47·699	32·344	32·389	32·366	....	....
" 31	20·387	20·443	1 01·470	−46·625	32·292	32·348	32·320	....	....
August 2	26·058	26·111	1 06·301	−47·549	32·208	32·261	32·235	....	....

Observers: { West W. C. Jaques.
{ East F. A. McDiarmid.

	h.	m.	s.
Mean		17	32·318
Longitude of Dawson	9	17	43·896
" Whitehorse	9	00	11·578

DIFFERENCE OF LONGITUDE BETWEEN PEMBROKE AND OTTAWA (DOMINION OBSERVATORY.)

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.	r.	
1907.	m. s.	m. s.	s.	s.	m. s.	m. s.	m. s.	s.	s.
August 3	5 00·156	5 00·051	20·118	14·358	5 34·632	5 34·527	5 34·580	·007	·077
" 6	00·484	00·403	20·790	13·373	647	566	606	·033	·040
" 7	00·830	00·761	20·870	12·899	599	530	564	·009	·035
" 8	00·689	00·617	21·343	12·546	578	506	542	·031	·036

	h.	m.	s.
Mean		5	34·573
Personal equation			·503
$\Delta\lambda$		5	35·076
λ Ottawa (Dom. Obs.)	5	02	51·797
λ Pembroke	5	08	26·873

Observers { West—C. A. French. East—R. M. Stewart.

DIFFERENCE OF LONGITUDE BETWEEN SUMMIT OF WHITE PASS AND DAWSON.

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.	v.	
1907.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.		
August 7	20 11·890	20 11·938	+ 1 08·510	1 52·938	17 10·442	17 10·490	17 10·466	...	
" 13	25·506	25·552	+ 1 11·599	− 2 03·609	10·298	10·344	10·321	....	..
" 16	38·978	39·064	1 14·001	2 14·640	10·337	10·423	10·380	....	...

Observers { West—W. C. Jaques.
East—F. A. McDiarmid.

	h.	m.	s.
Mean		17	10·389
Longitude of Dawson	9	17	43·896
Longitude of White Pass	9	00	33·507

DIFFERENCE OF LONGITUDE BETWEEN MATTAWA AND OTTAWA (DOMINION OBSERVATORY.)

Date.	Difference of Chronograph. Western Signals.	Difference of Chronograph. Eastern Signals.	Clock Correction. Western Station.	Clock Correction. Eastern Station.	Difference of Longitude. Western Signals.	Difference of Longitude. Eastern Signals.	Difference of Longitude. Mean.	Difference of Longitude. r.	Time of Transmission.
1907.	m. s.	m. s.	s.	s.	m. s.	m. s.	m. s.	s.	s.
August 22	11 42·760	11 42·674	5·566	8·911	11 57·177	11 57·091	11 57·134	·031	·043
" 23	42·729	42·631	5·740	8·709	57·178	57·080	57·129	·026	·049
" 28	36·056	35·960	13·102	7·917	57·075	56·979	57·027	·076	·045
" 29	35·299	35·209	13·989	7·878	57·166	57·076	57·121	·018	·045

Observers { West—C. A. French.
{ East—R. M. Stewart.

	h.	m.	s.
Mean		11	57·103
Personal equation			·503
$\Delta\lambda$		11	57·606
λ Ottawa (Dom. Obs.)	5	02	51·797
λ Mattawa	5	14	49·403

DIFFERENCE OF LONGITUDE BETWEEN LABELLE AND OTTAWA (DOMINION OBSERVATORY.)

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.	r	
1907.	m. s.	m. s.	s.	m. s.	m. s.	m. s.	m. s.		
September 17.	2 49·561	2 49·702	+7·792	+1 15·607	3 57·376	3 57·517	3 57·446	..	...
" 18	2 51 190	2 51 326	−7·577	1 13·621	3 57·234	3 57 370	3 57 302	. ..	. .

Observers { West—R. M. Stewart.
East—F. A. McDiarmid.

	h.	m.	s.
Mean		3	57·374
Longitude of Ottawa (Dom. Obs.) .	5	02	51·797
" Labelle	4	58	54 423

DIFFERENCE OF LONGITUDE BETWEEN CHAPLEAU AND OTTAWA (DOMINION OBSERVATORY).

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.	r.	
1907.	m. s.	m. s.	m. s.	s.	m. s.	m. s.	m. s.	s.	s.
Sept. 20.	32 01·978	32 01·765	1 23·624	7·052	30 45·406	30 45·193	30 45·300	093	106
" 21.	02·377	02·171	1 23·733	6·831	·475	·269	·372	021	103
" 22.	03·627	03·424	1 24·747	6·650	·530	·327	·428	035	102
" 25.	08·301	08·099	1 28·975	6·200	·526	·324	·425	032	101
" 30.	17·004	16·784	1 37·063	5·611	·552	·332	·442	019	110

Observers { West—C. A. French.
{ East—R. M. Stewart.

	h.	m.	s.
Mean		30	45·393
Personal equation			·503
Δλ		30	45·896
λ Ottawa (Dom. Obs.)	5	02	51·797
λ Chapleau	5	33	37·693

DIFFERENCE OF LONGITUDE BETWEEN ROBERVAL AND OTTAWA (DOMINION OBSERVATORY).

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals	Mean.	r	
1907.	m. s.	m. s.	s.	s.	m. s.	m. s.	m. s.		
Sept. 25	13 57·568	13 57·725	+ 6·733	- 6·727	13 57·562	13 57·719	13 57·640	. .	. .
Oct. 1	14 23·108	14 23·303	6·023	19·631	57·454	57·649	57·552	. .	. .

Observers { West—R. M. Stewart.
Observers { East — F. A. McDiarmid.

	h.	m.	s.
Mean		13	57·596
Longitude of Ottawa (Dom. Obs.)	5	02	51 797
" " Roberval	4	48	54 201

DIFFERENCE OF LONGITUDE BETWEEN LAKE EDWARD AND OTTAWA (DOMINION OBSERVATORY).

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.	r.	
1907.	m. s.	m. s.	s.	s.	m. s.	m. s.	m. s.		
Oct. 2	14 08·850	14 09·047	+ 5·930	−17·378	13 45·542	13 45·739	13 45·641	....	....
" 4	18·253	18·457	+ 5·726	26·917	45·610	45·814	45·712	....	....
" 5	24·289	24·388	+ 5·703	32·968	45·618	45·717	45·668	....	....

Observers: { West—R. M. Stewart.
East—F. A. McDiarmid.

	h.	m.	s.
Mean..		13	45·674
Longitude of Ottawa (Dom. Obs.).	5	02	51·797
" " Lake Edward...	4	49	06·123

DIFFERENCE OF LONGITUDE BETWEEN SCOTIA JUNCTION AND OTTAWA (DOMINION OBSERVATORY).

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.	r	
1907.	m. s.	m. s.	s.	s.	m. s.	m. s.	m. s.	s.	s.
Oct. 8	14 43·357	14 43·249	29·941	5·623	14 19·039	14 18·931	14 18·985	·047	·054
" 13	15 01·122	15 01·029	17·498	5·408	19·032	18·939	18·986	·046	·047
" 18	15 07·398	15 07·280	53·755	5·497	19·140	19·022	19·081	·049	·059
" 20	15 10·470	15 10·393	56·967	5·613	19·116	19·039	19·077	·045	·039

Observers { West—C. A. French.
East—R. M. Stewart.

	h.	m.	s.
Mean		14	19·032
λ Ottawa (Dom. Obs.)	5	02	51·797
λ Scotia Junction	5	17	10·829

DIFFERENCE OF LONGITUDE BETWEEN RIVIERE A PIERRE AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.	r.	
1907.	m. s.	m. s.	s.	m. s.	m. s.	m. s.	m. s.		
Oct. 13	12 51·586	12 51·729	+5·426	1 21·865	14 08·025	14 08·168	14 08·097	....	....
" 15	12 39·435	12 39·662	+5·408	1 33·927	14 07·954	14 08·181	14 08·068	....	....

Observers { West R. M. Stewart.
{ East W. C. Jaques.

	h.	m.	s.
Mean		14	08·083
Longitude of Ottawa (Dom. Obs.)	5	02	51·797
" Riviere à Pierre	4	48	43·711

DIFFERENCE OF LONGITUDE BETWEEN BARRY BAY AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.		Difference of Longitude.				Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Eastern Station.	Western Signals.	Eastern Signals.	Mean.	v.	
1907.	m. s.	m. s.	s.	s.	m. s.	m. s.	m. s.	s.	s.
Oct. 26	8 01·311	8 01·267	16·590	6·083	7 50·804	7 50·760	7 50·782	·047	·022
" 30	08·397	08·361	24·259	6·616	50·754	7 50·718	7 50·736	·001	·018
" 31	10·455	10·435	26·599	6·841	50·697	7 50·677	7 50·687	- ·048	·010

Observers { West—C. A. French.
East—R. M. Stewart.

	h.	m.	s.
Mean		7	50·735
λ Ottawa (Dom. Obs.)	5	02	51·797
λ Barry Bay	5	10	42 532

LONGITUDE AND LATITUDE OF STATIONS OBSERVED IN 1907.

Place.	Difference of Longitude.	To.	Longitude.	Longitude.	Latitude.
	m. s.		h. m. s.	° ' "	° ' "
Dawson	6 16·131	Boundary	9 17 43·896	139 25 58·44	64 03 23·15
Selkirk	8 13·294	Dawson	9 09 30·602	137 22 39·03	62 46 20·98
Tantalus	12 35·313	"	9 05 08·583	136 17 08·75	62 05 28·56
Whitehorse	17 32·318	"	9 00 11·578	135 02 53·67	60 43 17·17
Pembroke	5 34·573	Dominion Observatory	5 08 26·873	77 06 43·10	45 49 42·15
White Pass	17 10·389	Dawson	9 00 33·507	135 08 22·61	59 37 28·66
Mattawa	11 57·103	Dominion Observatory	5 14 49·403	78 42 21·05	46 18 40·55
Labelle	3 57·374	" "	4 58 54·423	74 43 36·35	46 17 02·27
Chapleau	30 45·393	" "	5 33 37·693	83 24 25·40	47 50 31·21
Roberval	13 57·596	" "	4 48 54·201	72 13 33·02	48 31 03·68
Lake Edward	13 45·674	" "	4 49 06·123	72 16 31·85	47 39 34·25
Scotia Junction	14 19·032	" "	5 17 10·829	79 17 42·44	45 30 46·75
Rivière à Pierre	14 08·083	" "	4 48 43·714	72 10 55·71	46 59 16·90
Barry Bay	7 50·735	" "	5 10 42·532	77 40 37·98	45 29 17·11
Michipicoten Harbour					47 57 40·16

LOCAL POSITIONS OF ASTRONOMICAL STATIONS.

Dawson.—The pier is 168·3 feet east and 7·1 feet north of the southeast corner of the Administration Building.

Selkirk.—The pier is 32 feet east and 22·5 feet south of the northeast corner of the Government Telegraph Office.

Tantalus.—The pier is 150·8 feet north and 32 feet west of the northwest corner of the Northwest Mounted Police Barracks.

Whitehorse.—The pier is just behind the Government Telegraph Office, and is 336·1 feet north and 379·7 feet west of the middle point of crossing of Main street and the White Pass and Yukon Railway.

Pembroke.—The pier is 98·2 feet north and 167·5 feet east of the intersection of the easterly limit of John street with the southerly limit of Wellington street.

White Pass.—The pier is 111·1 feet north and 45·9 feet west of the bronze monument on the Canada-Alaska boundary line at summit of White Pass.

Mattawa.—The pier is 419·6 feet west and 56·2 feet south of the southwest corner of the Canadian Pacific Railway station house.

Labelle.—The pier is 1,685 feet east and 82 feet south of the middle point of crossing of the Canadian Pacific Railway and Berthiaume road. This crossing is about 470 feet east of the Canadian Pacific Railway station house.

Chapleau.—The pier is 174·7 feet west and 432·3 feet south of the railway crossing sign board of the Canadian Pacific Railway. This crossing is about 300 feet west of the Canadian Pacific Railway station house.

Roberval.—The pier is 138·2 feet north and 47·1 feet west of the middle point of crossing of the Quebec and Lake St. John Railway and the Roberval road.

Lake Edward.—The pier is 332·4 feet east and 40·6 feet north of the northeast corner of the Quebec and Lake St. John Railway station house.

Scotia Junction.—The pier is about one-half mile east of the Grand Trunk Railway station house and is 249·4 feet north and 7·5 feet east of the sign post at the Grand Trunk Railway crossing.

Rivière à Pierre.—The pier is 120·2 feet west and 39·3 feet north of the northwest corner of the Quebec and Lake St. John Railway station house.

Barry Bay.—The pier is about 200 feet south of the Grand Trunk Railway station house and is 106·9 feet south and 1·1 feet east of the northeast corner of the Balmoral Hotel.

Michipicoten Harbour.—The pier is 45 feet north and 104 feet west of the northwest corner of the Algoma Inn.

Dominion Observatory.—The reference point of the longitudes observed in 1907 is a temporary transit house, the meridian of which is $0^s{\cdot}12$ east of the centre of the dome of the observatory.

APPENDIX 5.

REPORT OF THE CHIEF ASTRONOMER, 1908.

STATEMENT OF WORK PERFORMED IN THE PHOTOGRAPHIC DIVISION

BY

J. D. WALLIS.

APPENDIX 5.

STATEMENT OF WORK DONE IN THE PHOTOGRAPHIC DIVISION.

—	Size of plates and prints.											Total.
	$3\frac{1}{4} \times 4\frac{1}{4}$	4 x 5	$4\frac{1}{4} \times 6\frac{1}{2}$	5 x 7	8 x 10	10 x 14	11 x 14	16 x 20	24 x 36	8 x 36	30 x 40	
Plate negatives			821		117		63	84				1,085
Film negatives		170										170
Black and white and blue prints											41	41
Platinum prints				60								60
Argo paper prints		284	476	1,821	395							2,976
Bromide prints						1,542	113	401	36	103	13	2,208
Transparencies	135											135
Seismograms										365		365
Sun plates developed					244							244
Total	135	454	1,297	1,881	756	1,542	176	485	36	468	54	7,284

J. D. WALLIS,
Photographer.

APPENDIX 6.

REPORT OF THE CHIEF ASTRONOMER, 1908.

DETERMINATION OF THE ORBITS OF SPECTROSCOPIC BINARIES

BY

W. F. KING, LL.D.

ILLUSTRATIONS.

APPENDIX 6.

(Reprinted from the *Astrophysical Journal,* Vol. XXVII, No. 2.)

DETERMINATION OF THE ORBITS OF SPECTROSCOPIC BINARIES.

By W. F. King, LL.D.

On the assumption that the orbit of the star is an ellipse described about a centre of force in one focus, the graph formed by taking the velocities in the line of sight as ordinates and the corresponding times as abscissas will be a periodic curve, from which can be determined the elements of the orbit, viz., the periodic time, the eccentricity, the longitude of the periastron from the ascending node, the projection of the major axis upon the line of sight, and the velocity of the system as a whole, that is, of the center of gravity of the system or of the focus of the elliptic orbit.

Various methods of determining these elements have been given, either geometrical, like that of Lehmann-Filhés, depending upon the comparison of areas of certain parts of the curve; or analytical, like that of Russell, using a Fourier series.

The curve of observed line-of-sight velocities differs from the true curve, by reason of errors of observation. The method of least squares may be employed to correct the first values of the elements, and to give the most probable values.

Spectra of certain types, however, are difficult to measure with accuracy, with the result that the graph of observed velocities may present differences from the theoretical curve which bear a considerable ratio to the velocity, so that the method is not to be depended upon unless successive approximations are made, entailing much labour. In such cases correction of the graph may be resorted to.

A free-hand curve is drawn, as nearly as possible of the form which the velocity curve should have, and as nearly as possible representing the observations. This curve may be adjusted so as to fulfil certain theoretical conditions, as to equality of areas, &c. (Lehmann-Filhés method). From this curve the elements are determined and from them an 'ephemeris' is computed and a new graph representing these elements is drawn. Comparison of this with the former curve indicates correction to the elements, whereby a better accordance with observations may be secured. A new ephemeris with corrected values of the elements is then made, followed by a comparison with the observations. By successive trials in this way, the values of the elements most nearly according with the observations are finally determined. This is the method which has been followed here in obtaining the elements of the orbits of early type stars, and I notice by some orbits recently published by the Lick Observatory, that the same procedure has been adopted there.

The object of the present paper is to present a method whereby as much as possible of the work of testing the accuracy of the successive graphs and of preparing the ephemerides may be done graphically.

Let the ellipse ABA_1B_1 in Fig. 1 represent the orbit of the star, S the centre of force at the focus, AA_1 the major axis, N the ascending node, N_1 the descending node. Let P be the position of the star in its orbit at any time. We will suppose the motion of P to be clockwise. Draw SY perpendicular to the tangent at P. The

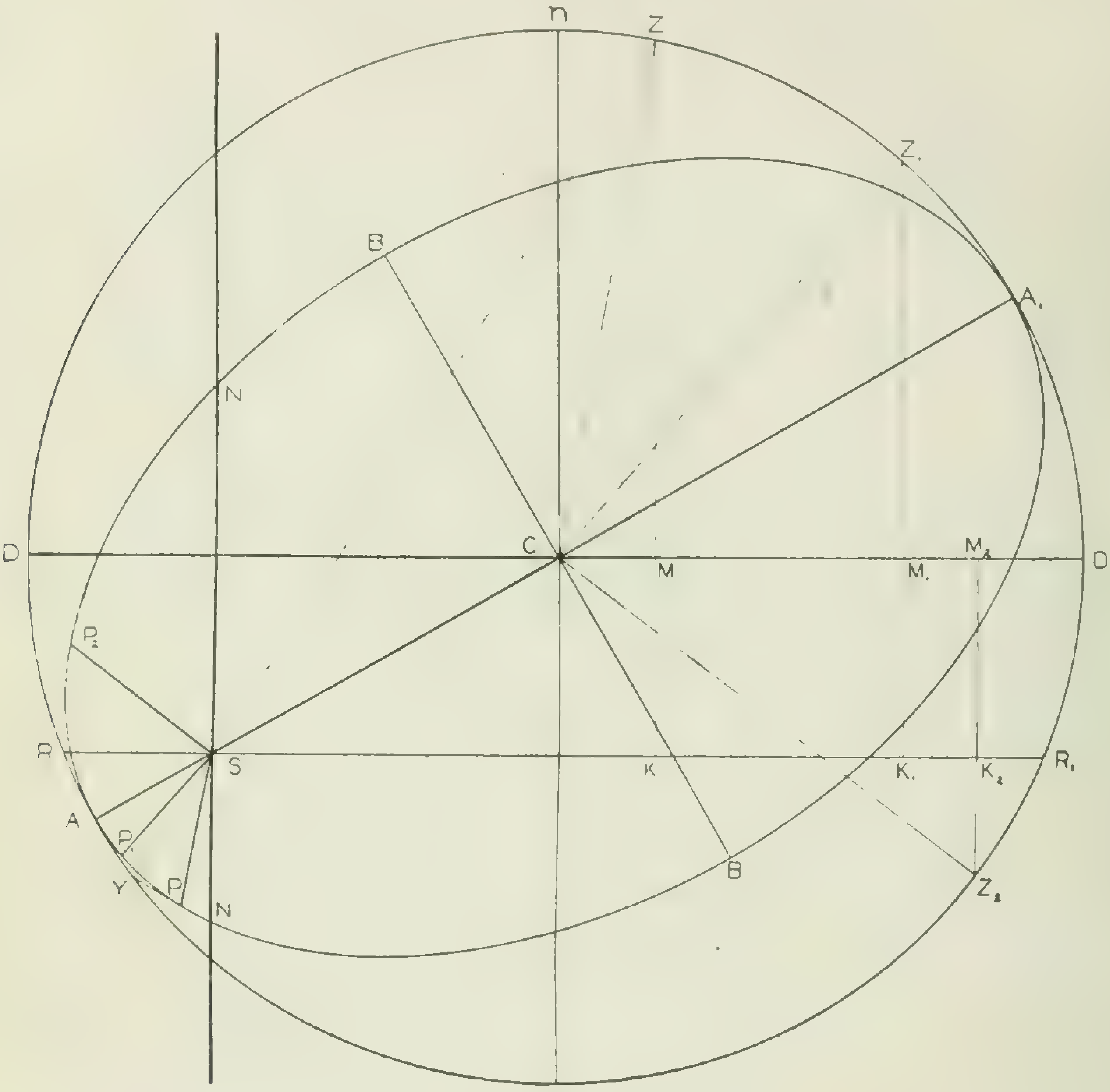

Fig. 1.

point Y will, by a property of the ellipse, fall on the circle AZZ_1A_1, described on the major axis as diameter. If h is twice the area described in the unit time, v the velocity of the body in its orbit (with reference to S considered fixed). And if we produce YS to meet the circle again in Z,

$$SY \cdot SZ = SA_1 \cdot SA = a^2(1-e)^2.$$

Hence

$$v = \frac{h}{a^2(1-e^2)} \cdot SZ.$$

SZ therefore is proportional to the velocity at P. It is perpendicular to its direction. Therefore the circle AZZ_1A_1 is the hodograph of the orbit, changed in scale in the ratio $1 : \frac{a^2(1-e^2)}{h}$ and turned through a right angle.

Draw RSR_1 through S, and DCD_1 through the centre C, perpendicular to the line of nodes. Draw ZMK perpendicular to these two lines and cutting them in M

and K. Then ZK is proportional to that component of the velocity relative to S, which is perpendicular to the line of nodes and in the plane of the orbit. If the plane of the orbit is inclined to the line of sight at an angle $90° - i$, $ZK \sin i$ is proportional to the velocity in the line of sight.

Multiplying all the ordinates, as ZK, of the circle by $\sin i$, we evidently find for the hodograph of velocities in the line of sight an ellipse, of which the semi-major axis is proportional to CD or a, and the semi-minor axis to $a \sin i$.

It is to be observed that, by a property of the ellipse and the circle on its major axis CZ is parallel to SP. When, therefore, P proceeding from the ascending node has turned an angle u about the focus, the corresponding point of the elliptic hodograph has the eccentric angle u (counted from the minor axis). The velocity in the line of sight (still considering S at rest) is therefore

$$(ZM + MK) \sin i = a \sin i \cos u + MK \sin i.$$

This consists of a constant part $MK \sin i$ which is equal to $SM \sin i \cos \omega$ (ω denoting the longitude of the apse counted from the ascending node) or $ae \sin i \cos \omega$; and a variable part $a \sin i \cos u$.

Let us now conceive the scale of the figure to have been changed by multiplying all lines in it by $\frac{h}{a^2(1-e^2)}$; then the circle AZZ_1A_1 becomes the hodograph in the

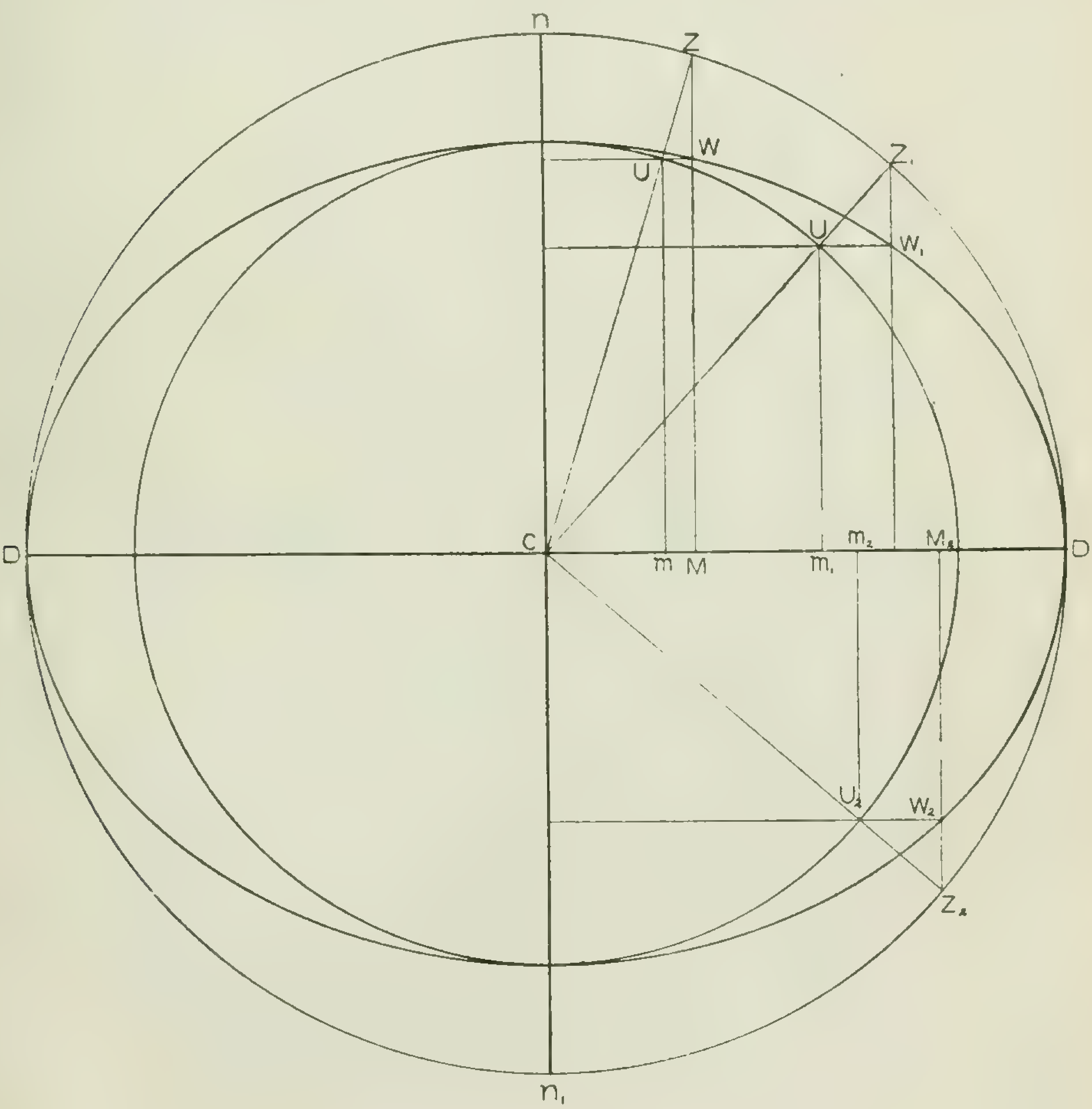

FIG. 2.

orbit, and the ellipse produced by multiplying the ordinates perpendicular to RSR_1 by sin i becomes the hodograph of observed velocities. Comparing this ellipse with the graph of observed velocities in the line of sight, we see (assuming that the observations are without error) that the two curves have the same ordinates but different abscissas; those of the graph being proportional to the time, those of the ellipse being proportional to the sine of the eccentric angle counted from the minor axis, that is, to the sine of the longitude (u) counted from the periastron.

Fig. 2 shows by the circle $AZZ_1 A_1$ the orbital hodograph, and by the ellipse $AWW_1 A_1$ the hodograph of the line of sight, having the ordinates MW, $M_1 W_1$, &c., equal to MZ sin i, $M_1 Z_1$ sin i, &c. Reduce all the abscissas of the ellipse in the same ratio, multiplying by sin i. Then the ellipse becomes the circle $UU_1 U_2$ described on the minor axis as diameter.

By consideration of the similar triangles ZMC, UMC, &c., it is seen that the new positions U, U_1 . . . . of the points W, W_1, W_2 fall on the straight lines joining C with Z, Z_1, Z_2, &c. Therefore the longitudes are unchanged, and the circle U, U_1, U_2, may be used as the equivalent of the hodograph of observed velocities. The problem is reduced to comparison of a circle with a curve in which the abscissas are proportional to the time.

The radius of this circle may be denoted by K. In terms of the elements of the ellipse

$$K = a\frac{h}{a^2(1-e^2)}\sin i = \frac{h \sin i}{a(1-e^2)}.$$

h is found from the periodic time U, for

$$h = \frac{2\pi a^2 \sqrt{1-e^2}}{U}.$$

$$\therefore K = \frac{2\pi a}{U\sqrt{1-e^2}} \sin i.$$

K is equal to one-half the difference between the maximum and minimum velocities in the line of sight. When this and e have been found with the desired precision, the value of a sin i follows from the above formula. Figs. 3 and 4 will serve to illustrate the application in practice of the foregoing principles.

First of all, the observed velocities having been plotted as ordinates with the times as abscissas, a free-hand curve is drawn approximately of the peculiar form of the theoretical curve, and passing through or near to the points representing the individual observations. The curves in the figures may be taken as representing more or less closely such a graph of observations. In the figures the curves have been drawn with exactness for two eccentricities, 0·75 and 0·10. A circle is drawn having for diameter the difference between the maximum and minimum ordinates, and having its centre on the line midway between the maximum and minimum points. This line, parallel to the axis of abscissas, may be called the central line of the curve.

The periodic time having been determined in the usual way, the abscissa-length corresponding to it is divided into any convenient number of equal parts, say 40; it should be an even number. The ordinates for these abscissas are placed in the circle, and the points so found in the circumference of the latter are marked. If the curve is of correct form, the points marked on the circumference will be found to lie at unequal distances from one another (except when the eccentricity of the orbit is zero), but these unequal distances will be found to vary uniformly. The points will be close together in the vicinity of one point of the circle, and will gradually separate as we proceed in either direction therefrom, until at the diametrically opposite point they reach their maximum distance apart. It is evident that the former point will correspond to aspastron, and that of widest separation to periastron.

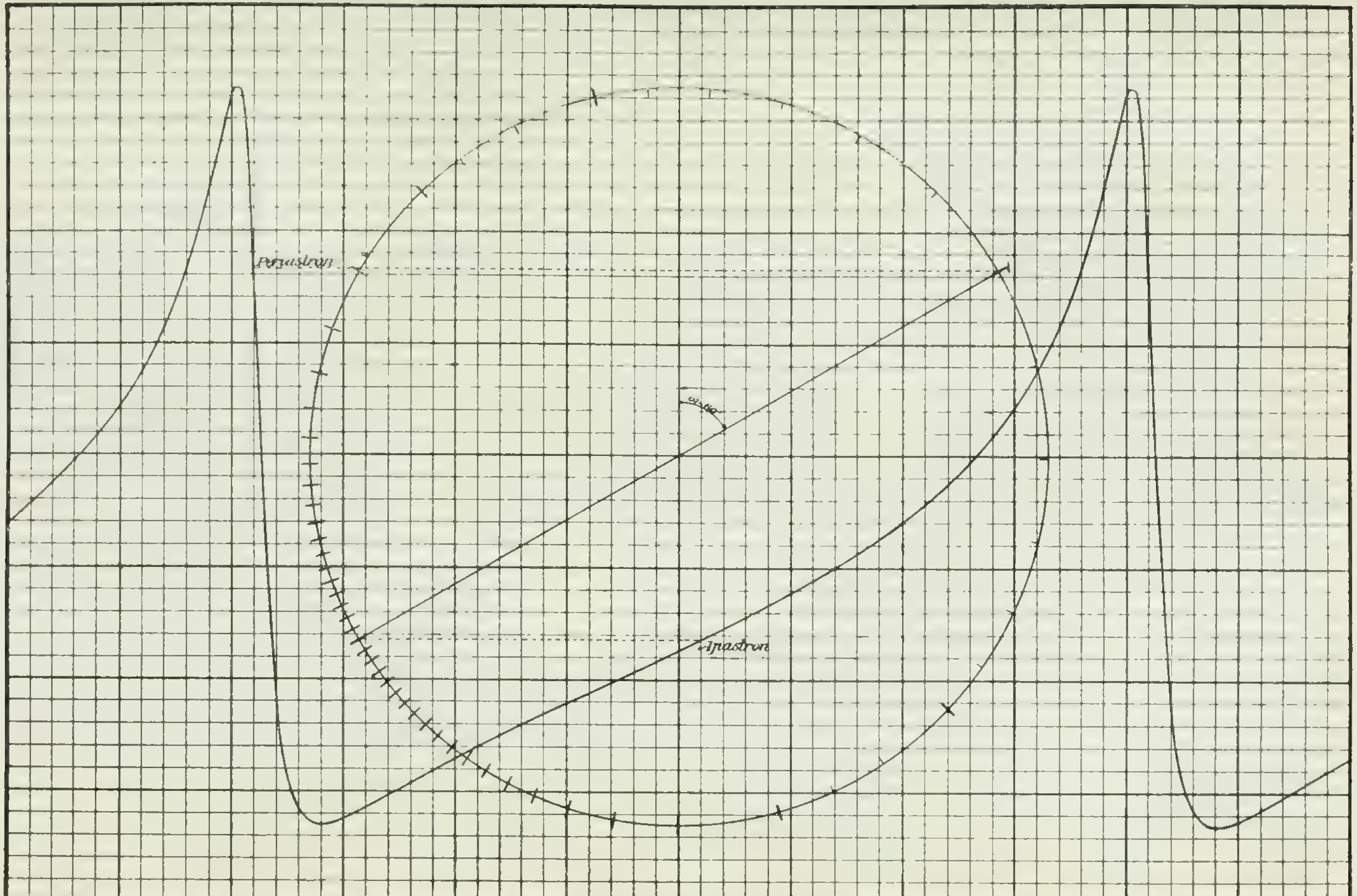

FIG. 3 Graph for $e = 0.75$, $\omega = 60$.

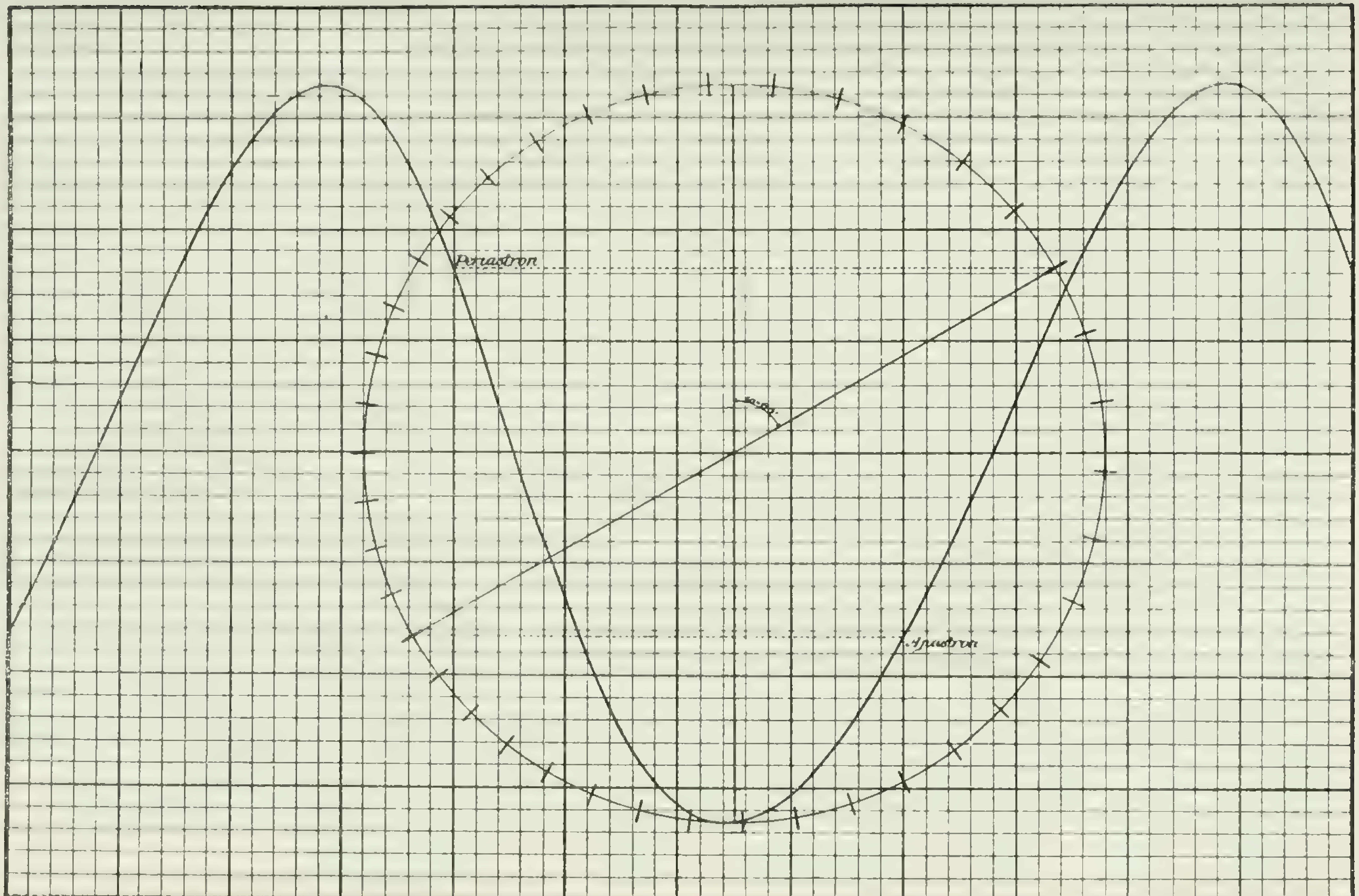

Fig. 4. Graph for $e = 0.10$, $\omega = 60°$

If it chances that one of the points of division of the line of abscissas corresponds to an apse, the divisions of the circumference will be equal at equal distances from the apsidal diameter. If not, they will not be equal on the two sides of this diameter, and the periastron will not coincide exactly with a division, but will lie within the greatest division of the circumference. Apastron similarly lies within the least division. We may, if we please, use the approximate positions of the apses thus found to set off our fortieths of the period along the line of abscissas from a new origin, whereby two of the points of the circle will more closely coincide with the apsidal points. In this manner, given a graph sufficiently near to the theoretical form, the position of the apsidal diameter may be determined and the angle which it makes with the axis of y measured with a protractor. This angle is the longitude (ω) of the apse.

It will be observed that this process furnishes a more thorough test of the accuracy of the graph than the method of equality of areas. If it is imperfect, the points on the circumference of the circle will not be distributed according to the regular order of increase or decrease of the included arcs. If an ordinate of the graph is too long or too short, the corresponding point on the circumference will be too near or too far from the vertical diameter.

If the points of maximum and minimum velocity have not been well determined, the diameter of the circle will be too long or too short. In the former case all the points on the circumference will be crowded away from the vertical diameter; in the latter, toward it. Since the arcs of the circle represent differences of longitude corresponding to the given intervals of time, and $\frac{du}{dt}$ varies inversely as the square of the distance from the focus, we have by measuring the lengths d and d_1 of the arcs at points whose longitudes from the periastron are θ and θ_1,

$$\frac{d}{d_1} = \frac{(1 + e\cos\theta)^2}{(1 + e\cos\theta_1)^2},$$

whence the eccentricity may be found, when the position of periastron is known. If we measure the arcs at periastron and apastron, we have

$$\frac{d}{d_1} = \left(\frac{1 + e}{1 - e}\right)^2.$$

In applying this method, it is usually sufficient to measure the chords instead of the arcs, as only an approximation is needed at this stage. If the eccentricity is so large as to so greatly increase the arcs near periastron that they may not be considered equal to their chords, additional points may be interpolated near periastron.

It is not advisable, however, to spend too much time on these preliminary processes, as it is hardly possible that the first graph should be drawn with sufficient accuracy to give a good final result. The approximate value of the longitude of the apse and the eccentricity is, however, needed for the construction of a better graph, or 'ephemeris.'

The process in use here of approximate determination of the elements and constructing an ephemeris is as follows: Using the analytical formulæ, the true anomalies corresponding to aliquot parts of the period of the binary are computed for any assumed eccentricity, and set off on the circumference of a circle, to be used as a protractor. A division of the period into 40 equal parts is in general convenient, though for high eccentricities a further subdivision must be made for the neighbourhood of periastron. The need for this is shown in Figs. 5, 6, and 7, which show protractors drawn for eccentricities 0·70, 0·75, and 0·80, respectively. The anomaly corresponding to one-fortieth of the period (or 9° of mean anomaly) is seen in Fig. 7 to be almost 90°. Intermediate lines near periastron have therefore been interpolated (shown dotted in the figures), dividing the one-fortieth next to periastron into 6 equal parts, each corresponding to 1°·5 of mean anomaly (this is found convenient

with the tables we use, which give the solution of Kepler's equation for every half-degree). The second interval from periastron has been divided into 3 equal parts (3° of mean anomaly).

In Figs. 8, 9, and 10, drawn for small eccentricities, 0·05, 0·10, and 0·15, respectively, the parts of the circumference are nearly equal throughout. A number of these protractors, on transparent celluloid, have been made here. After the ordinates of the curve have been transferred to the circle, and the circumference marked off, a choice among the protractors will show which one agrees most closely with the marked points, and thereby the values of the longitude of the apse and the eccentricity of the orbit are obtained. Tests here have shown that the eccentricity can thus be determined within 0·01 when the velocity-curve is accurately drawn. If not accurately drawn, no such close approximation is necessary.

To construct an ephemeris, given eccentricity e, apse longitude ω, range of velocity $2K$, and period U, proceed as follows:

Draw a circle of radius K. Draw its 'vertical' and 'horizontal' diameters, producing the latter to the length necessary for the period U, according to the time-scale adopted. Set the protractor, made for eccentricity e, with its centre over that of the circle, and its apsidal diameter making an angle ω with the vertical diameter. Plot the radial lines representing the anomalies corresponding to the divisions of the period upon the paper, noting their intersections with the circumference.

Having divided the line representing the period into a number of parts corresponding to the protractor, erect perpendiculars at these points of lengths equal to the corresponding ordinates of the circle. A free-hand curve drawn through the extremities of the ordinates gives the required curve or 'ephemeris.' If, as will usually happen, the observations are plotted and the graph drawn on cross-section paper, the procedure will be considerably shorter. Draw the circle of radius K on the same or a similar sheet, place centrally on it the transparent protractor with the periastron point at the proper longitude ω from the vertical diameter, and note the ordinates of the points of intersection of the circumference of the circle with the radial lines of the protractor. These ordinates can be at once placed on their corresponding abscissas without either drawing or measuring.

If a set of protractors, such as in use here for values of e differing by 0·05, is not available, an alternative procedure is to use an ordinary protractor to set off arcs of 10°, say, and then the abscissas of the time velocity curve may be made equal te the mean anomalies corresponding to true anomalies of every 10° around the orbit. This can easily be done with a set of tables, such as have been computed here, giving the parts of the period corresponding to true anomalies of every 10° for all values of e from 0 to 1, at intervals of 0·05.

When the ephemeris has been drawn, it may be redrawn to a different apsidal longitude in the manner following. In Fig. 11, draw CA and CB equal to the radius K of the generating circle, and including an angle (β) equal to that by which it is desired to change the apse-longitude. It is evident that if the point C be placed on the central line of the curve, and A on any point of the curve, the point D where the ordinate of A meets a line through B parallel to the axis of abscissas will be a point on the curve corresponding to an orbit, of the same eccentricity e, and apse-longitude $\omega + \beta$. For if the ordinate of A is $K \sin(\theta + \omega)$, θ being the true anomaly, that of D will be $K \sin(\theta + \omega + \beta)$, and the abscissa (the time) remains the same.

To decrease the apse-longitude, set B on the curve and find the point D_1 on the ordinate of B, such that AD_1 is parallel to the axis of abscissas.

In practice a curve may be converted very rapidly. Let the construction be made on cardboard. After drawing the lines CA and CB, describe a circle on AB as diameter. Cut this circle out of the cardboard, marking on its circumference the point A. Cut the cardboard so that there is a tolerably sharp point at C. If the curve has been drawn on cross-section paper, the intersection of the ordinate of A can be followed down by eye to its intersection with the circumference at D, and

25a- p. 338.

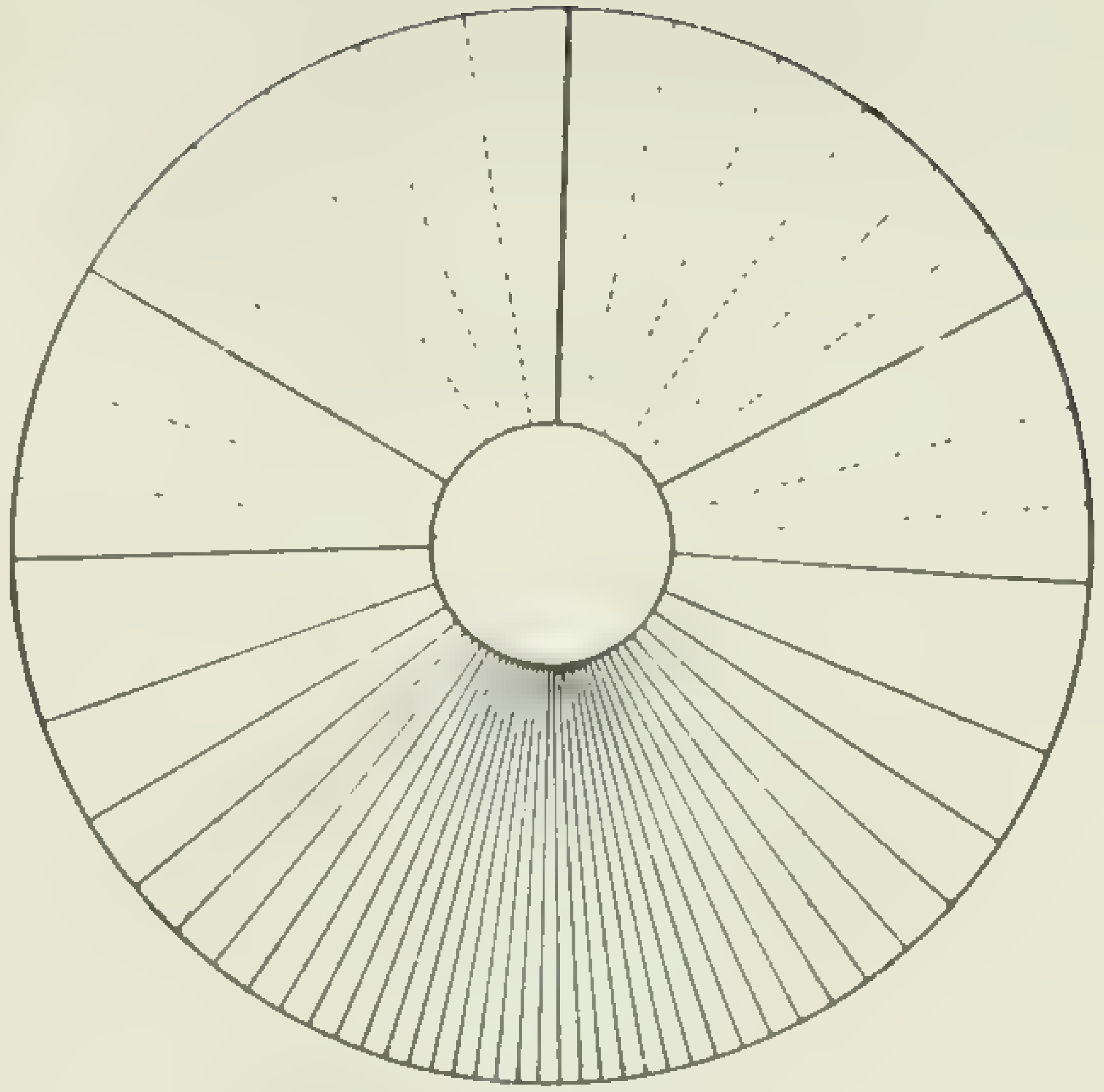
FIG. 5. $e=0.70$.

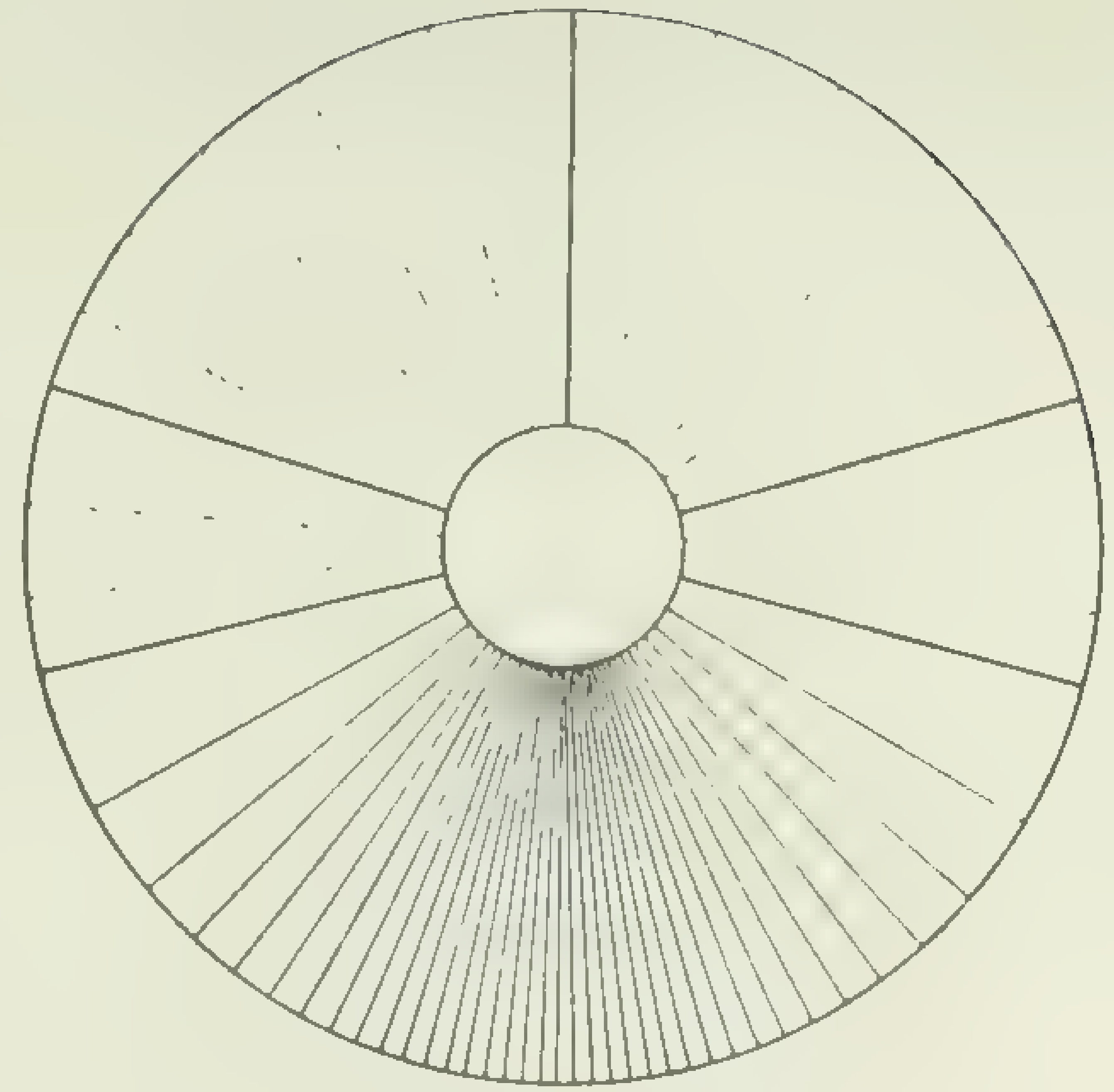
FIG. 6. $e=0.75$.

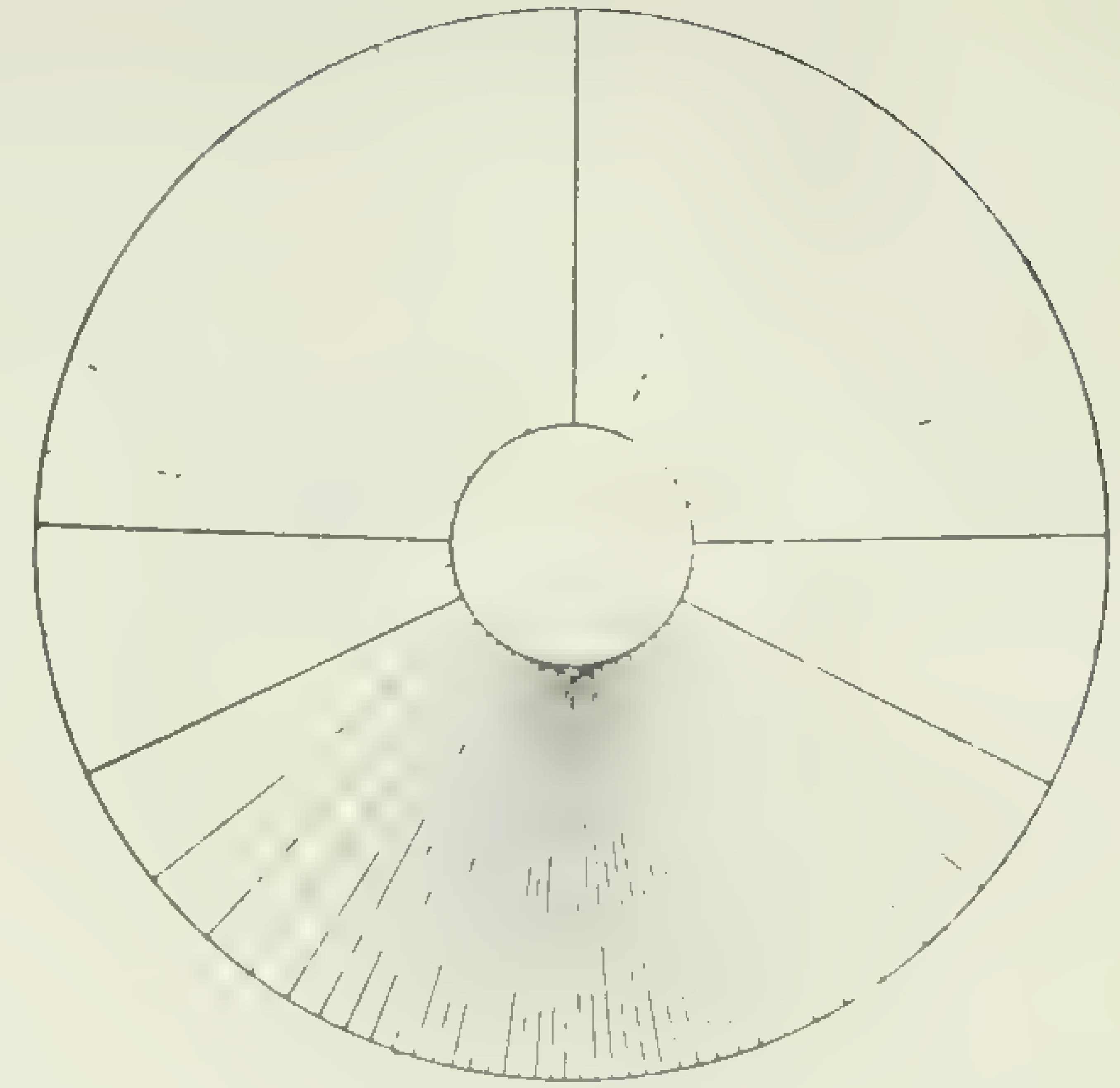
FIG. 7. $e=0.80$.

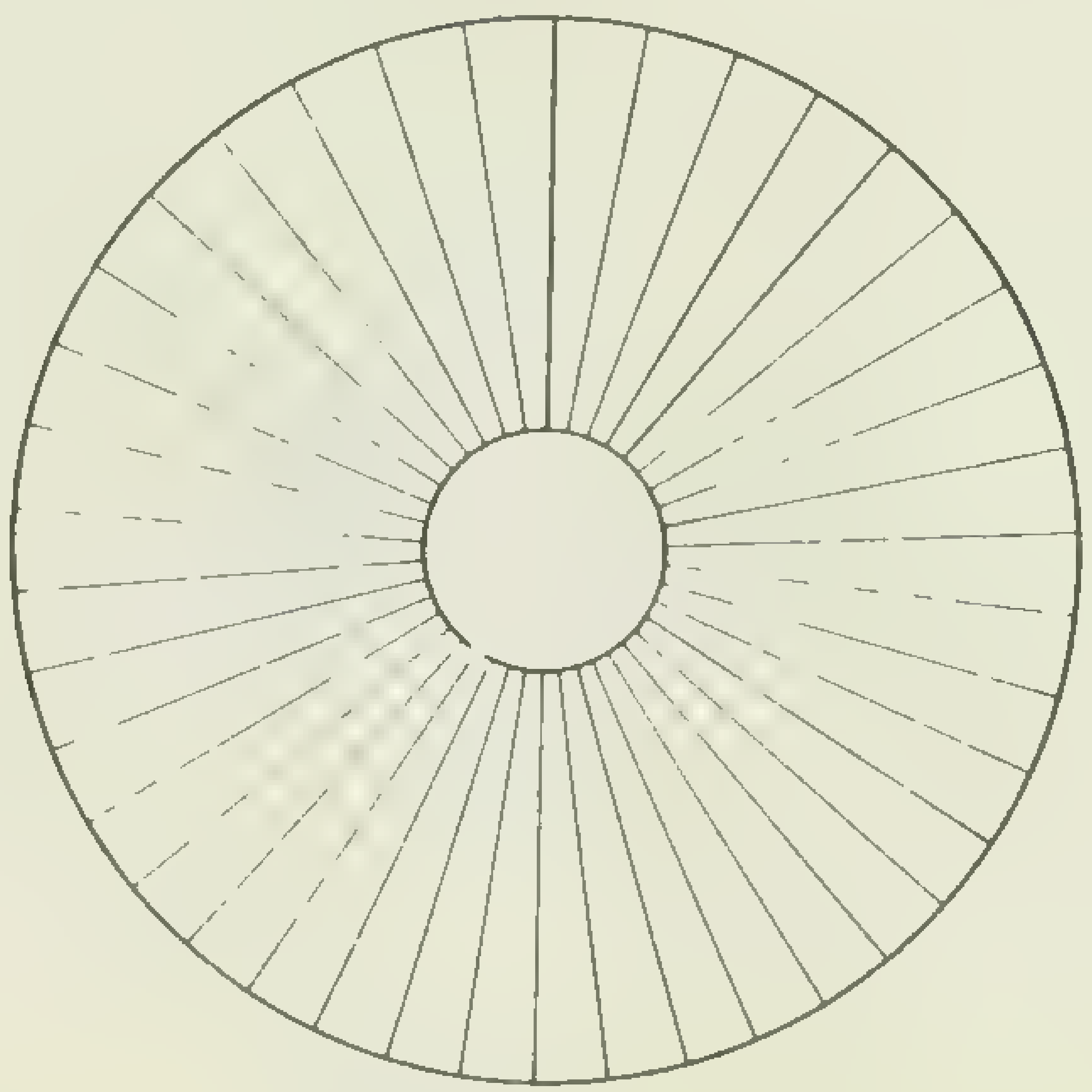
FIG. 8. $e=0.05$.

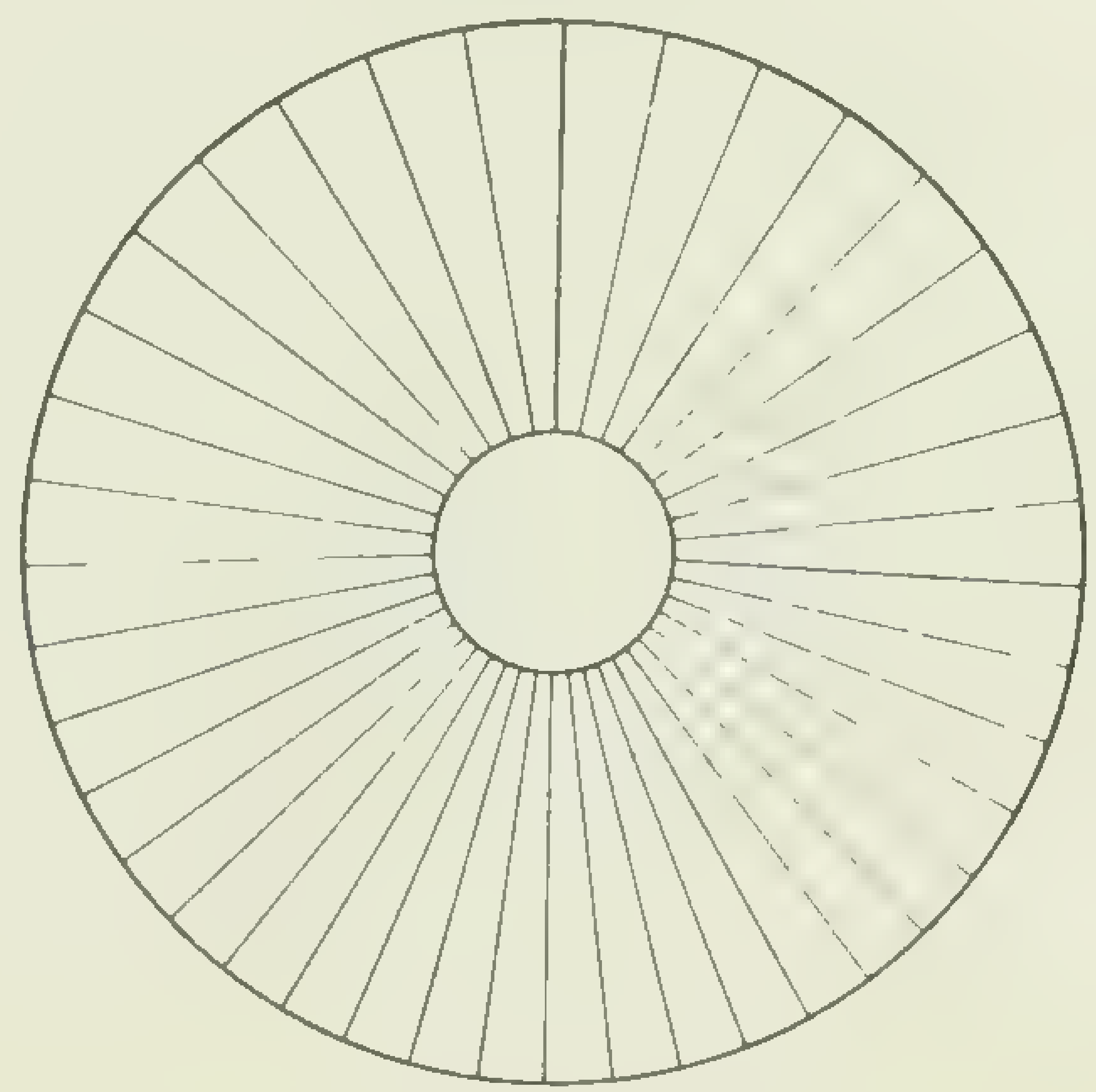
FIG. 9. $e=0.10$.

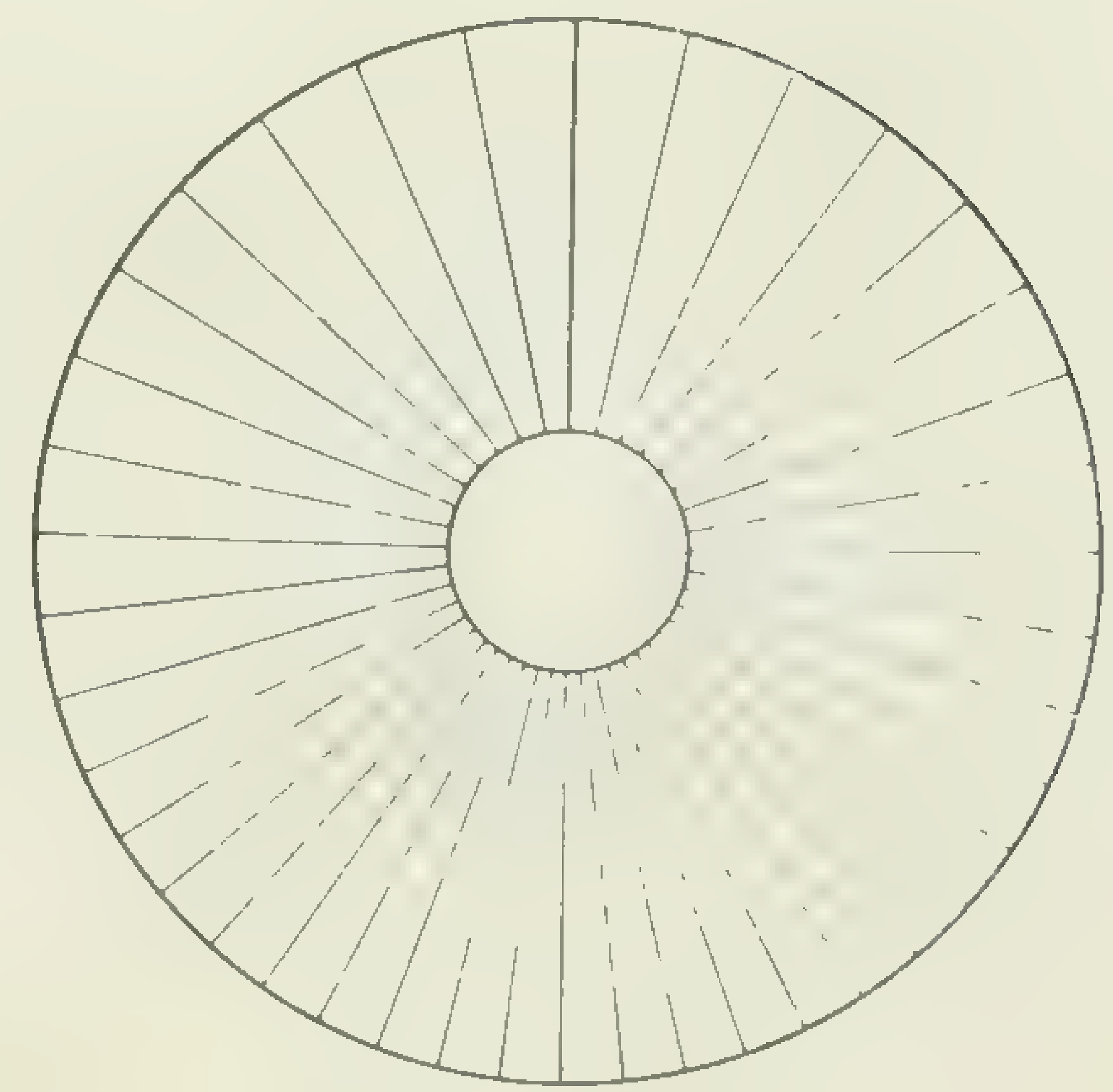
FIG. 10. $e=0.15$.

this point marked with a pencil. By operating thus with a number of points the curve can very rapidly be drawn to the changed apse-longitude.

If it is desired to change the scale of the velocities (i.e., the value of K) and the apse-longitude at the same time, this may be done by a slight modification of the construction above. Draw CA (Fig. 12) as before equal to K and $CB = K_1$ at an angle β with CA (to right or left according as increase or decrease of apse-longitude is

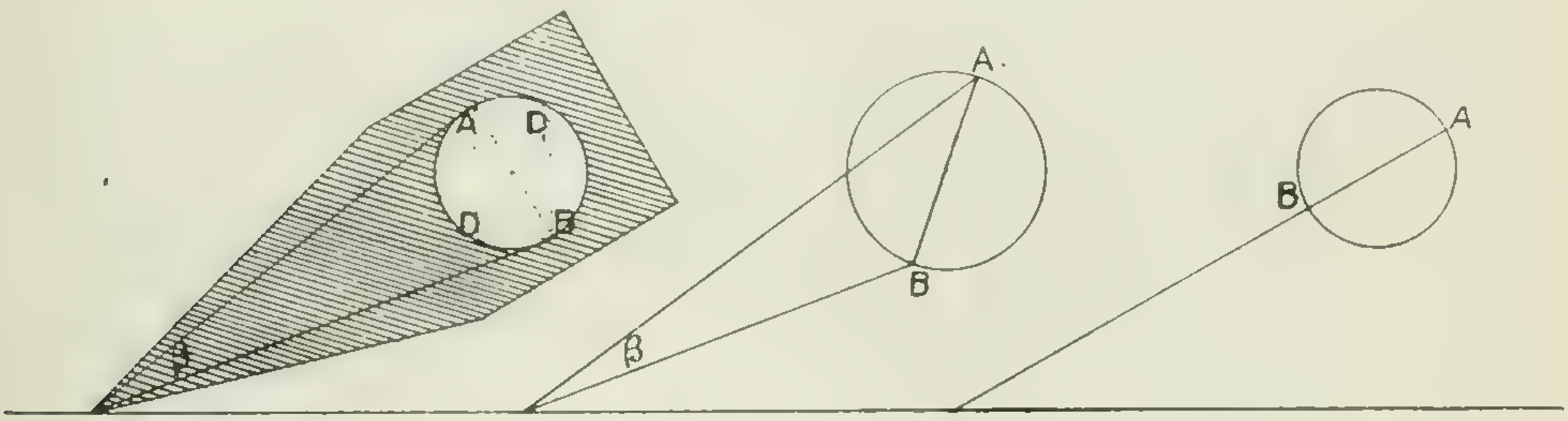

Fig 11 *Fig 12* *Fig 13*

required). Draw the circle on AB as diameter, and proceed as before to draw the amended curve.

If it is desired to change K to K_1 without changing ω, CA and CB are drawn in the same line (Fig. 13) and the circle is described on the diameter AB as before.

These constructions suggest another method of drawing an ephemeris.

Let a number of standard curves be drawn for different eccentricities, and for any convenient apse-longitude, which may be 0 or 90°, or have any other value. Such a curve will differ from the graph of the observations both in the scale of the abscissas and also in that of the ordinates, and in general in different ratios.

Both abscissas and ordinates may be reduced with the pantagraph to the scale of abscissas set by the length of the period of the binary, and then the further change of scale of ordinates to agree with that of the observed velocities may be made in the manner outlined above, and at the same time any required apse-longitude may be introduced. This method would have the advantage that the standard curve for a given eccentricity would need to be drawn but once, and therefore might be constructed very carefully. No convenient method of varying the eccentricity has yet been devised.

I wish to express my obligations to Mr. J. S. Plaskett for valuable assistance in preparing this paper for publication.

Dominion Astronomical Observatory,
January 31, 1908.

Since the above was published in the *Astrophysical Journal,* the following tables have been prepared. The first set contains the computed true anomalies for mean anomalies of every 9° around the orbit, with intermediate values in some places, used in constructing the protractors. The second set contains the fractions of the period corresponding to true anomalies of 10°. The former are computed for values of e between 0 and 1 at intervals of 0·05, the latter for values of e between 0 and 0·70 at intervals of 0·05 and between 0·70 and 1·00 at intervals of 0·025.

TRUE ANOMALY v.

M	·05		·10		·15		·20		·25		·30	
	°	'	°	'	°	'	°	'	°	'	°	'
9	9	58	11	2	12	18	13	44	15	25	17	24
18	19	53	22	1	24	26	27	13	30	25	34	6
27	29	46	32	52	36	18	40	14	44	38	49	36
36	39	34	43	29	47	48	52	36	57	52	63	37
45	49	14	53	50	58	52	64	16	70	5	76	14
54	58	48	63	56	69	26	75	12	81	14	87	29
63	68	14	73	46	79	30	85	25	91	29	97	35
72	77	32	83	16	89	6	94	59	100	52	106	41
81	86	42	92	28	98	14	103	55	109	31	114	58
90	95	43	101	23	106	56	112	20	117	32	122	32
99	104	36	110	1	115	17	120	17	125	4	129	34
108	113	20	118	26	123	16	127	49	132	7	136	8
117	121	58	126	37	130	59	135	2	138	48	142	20
126	130	29	134	36	138	26	141	58	145	13	148	13
135	138	53	142	25	145	41	148	37	151	22	153	52
144	147	12	150	7	152	44	155	8	157	19	159	18
153	155	28	157	40	159	41	161	28	163	7	164	36
162	163	40	165	10	166	30	167	43	168	48	169	48
171	171	50	172	36	173	17	173	53	174	25	174	55
180	180	00	180	00	180	00	180	00	180	00	180	00
189	188	10	187	24	186	43	186	7	185	35	185	5
198	196	20	194	50	193	30	192	17	191	12	190	12
207	204	32	202	20	200	19	198	32	196	53	195	24
216	212	48	209	53	207	16	204	50	202	41	200	42
225	221	7	217	35	214	19	211	23	208	38	206	8
234	229	31	225	24	221	34	218	2	214	47	211	47
243	238	2	233	23	229	1	224	58	221	12	217	40
252	246	40	241	34	236	44	232	11	227	53	223	52
261	255	24	249	59	244	43	239	43	234	56	230	26
270	264	17	258	37	253	4	247	40	242	28	237	28
279	273	18	267	32	261	46	256	5	250	29	245	2
288	282	28	276	44	270	54	265	1	259	8	253	19
297	291	46	286	14	280	30	274	35	268	31	262	25
306	301	12	296	4	290	34	284	48	278	46	272	31
315	310	46	306	10	301	8	295	44	289	55	283	46
324	320	26	316	31	312	12	307	24	302	8	296	23
333	330	14	327	8	323	42	319	46	315	22	310	24
342	340	7	337	59	335	34	332	47	329	35	325	54
351	350	2	348	58	347	42	346	16	344	35	342	36
360	360	00	360	00	360	00	360	00	360	00	360	00

TRUE ANOMALY *v*.

M	e											
	·35		·40		·45		50		·55		·60	
°	°	′	°	′	°	′	°	′	°	′	°	′
3	...	...	7	38	8	49	10	20	12	17	14	52
6	...	...	15	10	17	32	20	30	24	14	29	2
9	19	46	22	36	26	00	30	13	35	26	41	59
12	...	...	29	46	34	8	39	24	45	48	53	31
15	...	...	36	42	41	50	47	58	55	10	63	35
18	38	23	43	22	49	10	55	52	63	35	72	23
21	...	...	...	...	55	58	63	6	71	8	80	1
24	...	...	...	...	62	22	69	46	77	55	86	42
27	55	10	61	24	68	18	75	50	83	59	92	36
36	69	54	76	37	83	46	91	14	98	55	106	44
45	82	43	89	28	96	22	103	22	111	35	117	16
54	93	53	100	20	106	48	113	11	119	28	125	32
63	103	41	109	43	115	38	121	25	126	59	132	22
72	112	23	117	56	123	18	128	28	133	24	138	8
81	120	12	125	14	130	4	134	40	139	1	143	12
90	127	18	131	49	136	7	140	11	144	1	147	41
99	133	50	137	52	141	38	145	12	148	35	151	46
108	139	54	143	26	146	46	149	50	152	46	155	31
117	145	36	148	40	151	30	154	10	156	40	159	2
126	151	00	153	35	155	59	158	14	160	22	162	20
135	156	10	158	18	160	17	162	7	163	52	165	30
144	161	8	162	50	164	24	165	52	167	14	168	31
153	165	59	167	14	168	24	169	30	170	30	171	29
162	170	42	171	32	172	19	173	2	173	43	174	20
171	175	22	175	47	176	10	176	32	176	53	177	11
180	180	00	180	00	180	00	180	00	180	00	180	00
189	184	38	184	13	183	50	183	28	183	7	182	49
198	189	18	188	28	187	41	186	58	186	17	185	40
207	194	1	192	46	191	36	190	30	189	30	188	31
216	198	52	197	10	195	36	194	8	192	46	191	29
225	203	50	201	42	199	43	197	53	196	8	194	30
234	209	00	206	25	204	1	201	46	199	38	197	40
243	214	24	211	20	208	30	205	50	203	20	200	58
252	220	6	216	34	213	14	210	10	207	14	204	29
261	226	10	222	8	218	22	214	48	211	25	208	14
270	232	42	228	11	223	53	219	49	215	59	212	19
279	239	48	234	46	229	56	225	20	220	59	216	48
288	247	37	242	4	236	42	231	32	226	36	221	52
297	256	19	250	17	244	22	238	35	233	1	227	38
306	266	7	259	40	253	12	246	49	240	32	234	28
315	277	17	270	32	263	38	256	38	248	25	242	44
324	290	6	283	23	276	14	268	46	261	5	253	16
333	304	50	298	36	291	42	284	10	276	1	267	24
336	...	...	...	...	297	38	290	14	282	5	273	18
339	...	...	...	...	304	2	296	54	288	52	279	59
342	321	37	316	38	310	50	304	8	296	25	287	37
345	...	...	323	18	318	10	312	2	304	50	296	25
348	...	...	330	14	325	52	320	36	314	12	306	29
351	340	14	337	24	334	00	329	47	324	34	318	1
354	...	...	344	50	342	28	339	30	335	46	330	58
357	...	...	352	22	351	11	349	40	347	43	345	8
360	360	00	360	00	360	00	360	00	360	00	360	00

TRUE ANOMALY v.

M	e = ·65		·70		·75		·80		·85		·90		·95	
°	°	′	°	′	°	′	°	′	°	′	°	′	°	′
1·5	...	...	11	49	15	41	22	1	33	19	55	37	98	31
3	18	23	23	16	30	29	41	31	58	53	85	17	120	18
4·5	...	...	33	58	43	40	57	26	76	37	101	18	130	10
6	35	22	43	49	55	7	70	8	89	4	111	19	136	10
7·5	...	...	52	38	64	53	...	...	...	...	...	...	...	...
9	50	13	60	34	73	12	88	16	105	12	123	30	143	28
12	62	48	73	49	86	25	100	25	115	20	130	58	147	59
15	73	20	84	20	96	23	109	11	122	26	136	10	151	11
18	82	11	92	50	104	8	115	50	127	46	140	6	153	38
27	101	34	110	44	119	56	129	10	138	25	147	59	158	40
36	114	34	122	19	130	00	137	35	145	11	153	4	161	56
45	124	4	130	43	137	12	143	38	150	4	156	46	164	23
54	131	29	137	13	142	49	148	20	153	54	159	41	166	18
63	137	32	142	34	147	25	152	13	157	4	162	7	167	55
72	142	42	147	4	151	20	155	31	159	46	164	12	169	19
81	147	11	151	1	154	46	158	25	162	8	166	2	170	32
90	151	11	154	32	157	48	161	1	164	16	167	42	171	40
99	154	48	157	44	160	35	163	23	166	13	169	13	172	41
108	158	10	160	41	163	8	165	35	168	2	170	37	173	38
117	161	17	163	26	165	34	167	37	169	43	171	58	174	32
126	164	14	166	4	167	49	169	34	171	20	173	12	175	23
135	167	2	168	32	169	59	171	25	172	53	174	25	176	12
144	169	46	170	56	172	5	173	13	174	22	175	35	177	00
153	172	23	173	16	174	7	174	56	175	48	176	42	177	46
162	174	58	175	31	176	6	176	40	177	13	177	49	178	31
171	177	29	177	47	178	4	178	20	178	37	178	55	179	16
180	180	00	180	00	180	00	180	00	180	00	180	00	180	00
189	182	31	182	13	181	56	181	40	181	23	181	5	180	44
198	185	2	184	29	183	54	183	20	182	47	182	11	181	29
207	187	37	186	44	185	53	185	4	184	12	183	18	182	14
216	190	14	189	4	187	55	186	47	185	38	184	25	183	00
225	192	58	191	28	190	1	188	35	187	7	185	35	183	48
234	195	46	193	56	192	11	190	26	188	40	186	48	184	37
243	198	43	196	34	194	26	192	23	190	17	188	2	185	28
252	201	50	199	19	196	52	194	25	191	58	189	23	186	22
261	205	12	202	16	199	25	196	37	193	47	190	47	187	19
270	208	49	205	28	202	12	198	59	195	44	192	18	188	20
279	212	49	208	59	205	14	201	35	197	52	193	58	189	28
288	217	18	212	56	208	40	204	29	200	14	195	48	190	41
297	222	28	217	26	212	35	207	47	202	56	197	53	192	5
306	228	31	222	47	217	11	211	40	206	6	200	19	193	42
315	235	56	229	17	222	48	216	22	209	56	203	14	195	37
324	245	26	237	41	230	00	222	25	214	49	206	56	198	4
333	258	26	249	16	240	4	230	50	221	35	212	1	201	20
342	277	49	267	10	255	52	244	10	232	14	219	54	206	22
345	286	40	275	40	263	37	250	49	237	34	223	50	208	49
348	297	12	286	11	273	35	259	35	244	40	229	2	212	1
351	309	47	299	26	286	48	271	44	254	48	236	30	216	32
352·5	...	...	307	22	295	7	...	...	...	...	...	...	...	...
354	324	38	316	11	304	53	289	52	270	56	248	41	223	50
355·5	...	...	326	2	316	20	302	34	283	23	258	42	229	50
357	341	37	336	44	329	31	318	29	301	7	274	43	239	42
358·5	...	...	348	11	344	19	337	59	326	41	304	23	261	29
360·0	360	00	360	00	360	00	360	00	360	00	360	00	360	00

t IN TERMS OF θ.

Formula :— $$t = \frac{1}{2\pi}\left[2\tan^{-1}\left\{\sqrt{\frac{1-e}{1+e}}\tan\frac{\theta}{2}\right\} - \frac{e\sqrt{1-e^2}\,\mathrm{Sin}\,\theta}{1+e\,\mathrm{Cos}\,\theta}\right]$$

θ	e = ·00	e = ·05	e = ·10	e = ·15	e = ·20
10°	·02778	·02511	·02263	·02033	·01818
20°	·05555	·05030	·04539	·04081	·03653
30°	·08333	·07562	·06840	·06162	·05528
40°	·11111	·10117	·09178	·08293	·07457
50°	·13889	·12699	·11539	·10488	·09461
60°	·16667	·15314	·14014	·12765	·11566
70°	·19444	·17963	·16532	·15139	·13789
80°	·22222	·20662	·19132	·17627	·16151
90°	·25000	23409	·21822	·20243	·18677
100°	·27778	26200	·24507	·23000	·21380
110°	·30556	·29039	·27490	25905	·24290
120°	·33334	·31929	·30473	·28966	·27407
130°	·36111	·34862	·33552	·32180	·30740
140°	·38889	·37836	·36720	·35538	·34285
150°	·41667	·40861	·39965	·39027	·38030
160°	·44445	·43881	·43274	·42621	·41916
170°	·47222	·46936	·46626	·46291	·45927
180°	·50000	·50000	·50000	·50000	·50000
190°	·52778	·53064	·53374	·53709	·54073
200°	·55555	·56119	·56726	·57379	·58084
210°	·58334	·59156	·60035	·60973	·61970
220°	·61112	·62164	·63280	·64462	·65715
230°	·63890	·65138	·66448	·67820	·69260
240°	·66668	·68071	·69527	·71034	·72593
250°	·69445	·70961	·72510	·74095	·75710
260°	·72223	·73800	·75393	77000	·78620
270°	·75000	·76591	·78178	·79757	·81323
280°	·77777	·79338	·80868	·82373	·83849
290°	·80555	·82032	·83468	·84861	·86211
300°	·83334	·84686	·85986	·87235	·88434
310°	·86112	87300	·88461	·89512	·90539
320°	·88890	·89883	·90822	·91707	·92543
330°	·91667	·92438	·93160	·93838	·94472
340°	·94446	·94970	·95461	·95919	·96347
350°	·97222	·97489	·97737	·97967	·98182
360°	1·00000	1·00000	1·00000	1·00000	1·00000

θ	e = ·25	e = ·30	e = ·35	e = ·40	e = ·45
10°	·01616	·01430	·01256	01094	·00944
20°	·03254	·02881	·02532	·02208	·01905
30°	·04931	·04372	·03849	·03360	·02905
40°	·06669	·05926	·05229	·04575	·03962
50°	·08489	·07569	·06698	·05875	·05101
60°	·10420	·09323	·08283	·07291	·06353
70°	·12484	·11226	·10017	·08858	·07752
80°	·14710	·13305	·11940	10816	·09340
90°	·17127	·15596	·14092	·12616	·11175
100°	·19762	·18140	·16522	·14915	·13322
110°	·22645	·20975	·19285	·17578	·15860
120°	·25800	·24140	·22432	·20678	·18880
130°	·29235	·27655	·26008	24282	·22478
140°	·32955	·31544	·30040	·28441	·26735
150°	·36940	·35780	·34523	·33170	31697
160°	41154	·40324	39420	·38433	·37333
170°	·45532	·45500	·44624	·44098	·43513
180°	·50000	·50000	·50000	·50000	50000
190°	·54468	·54900	55376	·55902	·56487
200°	·58846	·59676	·60580	·61567	·62667
210°	·63060	·64220	·65477	·66830	·68303
220°	·67045	·68456	·69960	·71559	·73265
230°	·70765	·72345	·73992	·75718	·77522
240°	·74200	·75860	·77568	·79322	·81120
250°	·77355	·79025	·80715	·82422	·84140
260°	80238	·81860	·83478	·85085	·86678
270°	·82873	·84404	·85908	·89384	·88825
280°	·85290	·86695	·88060	·89384	·90660
290°	·87516	·88774	·89983	·91142	·92248
300°	·89580	·90677	·91717	·92309	·93647
310°	·91511	·92431	·93302	·94125	·94899
320°	·93331	·94074	·94771	·95425	·96038
330°	·95069	·95628	·96151	·96640	·97095
340°	·96746	·97119	·97468	·97792	·98095
350°	·98384	·98570	·98744	·98906	·99056
360°	1 00000	1·00000	1·00000	1·00000	1·00000

θ	$e = \cdot 50$	$e = \cdot 55$	$e = \cdot 60$	$e = \cdot 65$	$e = \cdot 70$
10°	·00805	·00676	·00557	·00449	00351
20°	·01626	·01367	·01128	·00938	·00712
30°	·02480	·02088	·01727	·01393	·01091
40°	·03392	·02858	·02367	·01913	·01501
50°	·04376	·03698	·03067	·02486	01954
60°	·05467	·04635	·03856	·03134	·02470
70°	·06699	·05701	·04763	·03885	·03074
80°	08115	·06944	·05833	·04782	·03801
90°	·09775	·08421	·07118	·05877	·04703
100°	·11751	·10210	·08708	·07252	·05855
110°	·14137	·12415	·10706	·09020	·07371
120°	·17042	·15170	·13267	·11347	·09422
130°	·20593	·18630	·16583	·14458	·12260
140	·24915	·22968	·20887	·18647	·16246
150°	·30091	·28330	·26389	·24234	·21825
160°	·36120	·34760	·33219	·31452	·29400
170°	·42855	·42110	·41263	·40231	·39015
180°	·50000	·50000	·50000	·50000	·50000
190°	·57145	·57890	·58737	·59769	·60985
200°	·63880	·65240	·66783	·68548	·70600
210°	·69909	·71670	·73611	·75766	·78175
220°	·75085	·77032	·79113	·81353	·83754
230°	79407	·81370	83417	·85542	·87740
240°	·82958	·84830	·86733	·88653	90578
250°	·85863	·87585	·89294	·90980	·92629
260°	·88249	·89790	·91212	·92748	·94145
270°	·90225	·91579	·92882	·94123	·95297
280°	·91885	·93056	94167	·95218	·96199
290°	·93301	·94299	·95237	·96115	·96926
300°	·94533	·95365	·96144	·96866	·97530
310°	·95624	·96302	·96933	·97514	·98046
320°	·96608	·97142	·97633	·98087	·98499
330°	·97520	·97912	·98273	·98607	·98909
340°	·98374	·98633	·98872	·99062	·99288
350°	·99195	·99324	·99443	·99551	·99649
360°	1·00000	1·00000	1·00000	1·00000	1·00000

θ	$e = ·725$	$e = ·750$	$e = ·775$	$e = ·800$	$e = ·825$
10°	·00307	·00263	·00224	·00185	·00151
20°	·00620	·00533	·00453	·00375	·00307
30°	·00951	·00816	·00695	·00576	·00471
40°	·01310	·01124	·00958	00794	·00650
50°	·01717	·01466	·01251	01038	·00850
60°	02161	·01860	·01588	·01320	·01082
70°	·02693	·02322	·01987	01654	·01358
80°	·03340	·02886	02475	·02066	·01700
90°	·04145	·03596	·03093	02592	·02139
100°	·05183	·04519	·03903	·03288	·02724
110°	·06565	·05762	·05007	·04246	·03540
120°	·08463	·07496	·06568	·05625	·04732
130°	·11138	·09986	·08858	·07691	·06558
140°	·14982	·13655	12318	·10902	·09476
150°	·20507	19090	·17610	·15996	·14300
160°	·28235	·26945	·25550	·23974	22232
170°	·38310	37506	·36612	·35568	·34363
180°	·50000	·50000	·50000	·50000	·50000
190°	·61690	·62494	63388	·64432	·65637
200°	·71765	·73055	·74450	·76026	·77768
210°	·79493	·80910	82390	·84004	·85700
220°	·85018	86345	87682	·89098	·90524
230°	·88862	·90014	·91142	·92309	·93442
240°	·91537	·92504	·93432	·94375	·95268
250°	·93435	·94238	·94993	·95754	·96460
260°	·94817	·95481	·96097	·96712	·97276
270°	·95855	·96404	·96907	·97408	·97861
280°	·96660	·97114	·97525	·97934	·98300
290°	·97307	·97678	·98013	·98346	·98642
300°	·97839	·98140	·98412	·98680	·98918
310°	·98293	·98534	·98749	·98962	99130
320°	·98690	·98876	·99042	·99206	·99350
330°	·99049	·99184	·99305	·99424	·99529
340°	·99380	·99467	·99547	·99625	·99693
350°	·99693	·99737	·99776	·99815	·99849
360°	1·00000	1·00000	1·00000	1·00000	1·00000

θ	$e = ·850$	$e = ·875$	$e = ·900$	$e = ·925$	$e = ·950$
10°	·00118	·00090	·00063	·00041	·00024
20°	·00240	·00183	·00129	·00084	·00044
30°	·00369	·00281	·00197	·00130	·00068
40°	·00509	·00388	·00273	·00179	·00094
50°	·00667	·00505	·00358	·00234	·00124
60°	·00850	·00649	·00456	·00299	·00158
70°	·01070	·00817	·00578	·00378	·00201
80°	·01342	·01026	·00729	·00478	·00255
90°	·01694	·01301	·00927	·00610	·00325
100°	·02170	·01673	·01198	·00791	·00427
110°	·02840	·02204	·01590	·01054	·00576
120°	·03841	·03006	·02195	·01475	·00814
130°	·05400	·04293	·03191	·02177	·01228
140°	·07984	·06496	·04963	·03479	·02032
150°	·12446	·10494	·08368	·06150	·03814
160°	·20226	·17958	·15280	·12165	·08399
170°	·32905	·31135	·28852	·25811	·21343
180°	·50000	·50000	·50000	50000	·50000
190°	·67095	·68865	·71148	·74189	·78658
200°	·79774	·82042	·84720	·87835	·91600
210°	·87554	·89506	·91632	·93850	·96186
220°	·92016	93504	·95037	·96521	·97968
230°	·94600	·95707	·96809	·97823	·98772
240°	·96159	·96994	·97805	·98525	·99185
250°	·97160	·97796	·98410	·98946	·99424
260°	·97830	·98327	·98802	·99209	·99572
270°	·98306	·98699	·99073	·99390	·99675
280°	·98658	·98974	·99271	·99522	·99745
290°	·98930	·99183	·99422	·99622	·99800
300°	·99150	·99351	·99544	·99701	·99840
310°	·99333	·99495	·99642	·99766	·99875
320°	·99491	·99612	·99727	·99821	·99906
330°	·99631	·99719	·99803	·99870	·99932
340°	·99760	·99817	·99871	·99916	·99955
350°	·99882	·99910	·99937	·99959	·99976
360°	1·00000	1·00000	1·00000	1·00000	1·00000

APPENDIX 7.

REPORT OF THE CHIEF ASTRONOMER, 1908.

THE GEODETIC SURVEY

BY

C. A. BIGGER, D.L.S.

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ILLUSTRATIONS.

APPENDIX 7.

REPORT OF C. A. BIGGER, D.L.S., ON THE GEODETIC SURVEY.

OTTAWA, ONT., August 5, 1908.

W. F. KING, Esq., B.A., LL.D.,
Chief Astronomer,
Department of the Interior,
Ottawa.

SIR,—As an introduction to a description of the geodetic work accomplished in Canada a short historical sketch may be of interest.

Geodetic surveys for geographical purposes have been in active progress in many countries for more than a century. Their inception was due to the advancement and development of scientific research. A more exhaustive and intelligent discussion of the size and figure of the earth became necessary in order that the disputes between scientific societies in the different European countries might be satisfactorily settled. The early history of geodetic work—prior to the beginning of the nineteenth century—is most interesting reading, but for the purpose of this report, may be passed over with a summary of its development.

The study of the size and figure of the earth is carried on by triangulation along arcs of meridians upon different portions of the earth's sphere, and necessarily includes astronomical observations for latitude and azimuth, thus supplying one of the two co-ordinates for mapping purposes. A desire for the comparison of results led to the connection of these triangulations transversely, which, together with the choice of a principal meridian, furnished the other co-ordinate called longitude.

The progress of civilization created a demand for accurate maps and the triangulations referred to, supplied stations of known latitude and longitude, thus bringing before the public the practical benefits of such work.

The earlier geodetic triangulations were for many reasons unsuccessful; no definite data as to the curvature of the earth's surface were derived therefrom, but the knowledge obtained served as an incentive to more work, and the rivalry between the countries more advanced in scientific knowledge became intense, especially in the fourth decade of the eigtheenth century. In 1735 and 1736 expeditions were organized by the French Academy of Sciences and their work in Peru and Lapland proved that the polar is longer than the equatorial degree of latitude.

Towards the latter part of the eighteenth century triangulations were in active progress in Great Britain and on the continent of Europe, and during the first decade of the nineteenth century the Great Triangulation Survey of India and the Geodetic Survey of the United States of America were commenced. The methods developed by these two surveys are recognized as the best modern practice.

BEGINNING OF THE GEODETIC SURVEY.

Up to the present, maps of eastern Canada have been compiled from the plans of township surveys, co-ordinated—in some instances—by railway surveys. When greater accuracy was desired, latitude and longitude observations were made at isolated stations. The requests for these astronomical stations became so frequent that it was deemed unwise to further postpone the beginning of a geodetic survey,

as geographical stations—determined by astronomical observations—are subject to the influence of the unequal distribution of gravity, and their displacement from this cause alone may amount to several hundred feet.

WORK OF 1905.

In 1905, the Chief Astronomer received the authority of the Minister of the Interior to commence a triangulation in the vicinity of Ottawa, and the writer was given charge of the work. On the 23rd day of July the first signal was erected on King mountain, about 9 miles northwest of Ottawa. (Plate 1.) An observing tower eighty-seven feet high was erected the same season near Bowesville, south of Ottawa. (Plate 2.) And a portion of the country between the Ottawa and St. Lawrence rivers was explored for the purpose of selecting angular points for the triangulation.

WORK OF 1906.

In 1906, nine towers of an average height of seventy-five feet were erected and reconnaissance extended east and west from Ottawa. Up to the end of 1906 the work was of a desultory nature owing to the small amount of money available for that purpose.

During the winter of 1906 and 1907, the writer and one assistant continued the reconnaissance east from the city of Ottawa across the southern portion of the province of Quebec as far as the southeastern boundary of that province.

WORK OF 1907.

In 1907 the Geodetic Survey of Canada was organized upon a somewhat more extensive scale and much work was accomplished during that season.

At the outset it was decided that the triangulation should be of the highest order of precision and the standard adopted, viz.: that the average summation of the three observed angles of each triangle should be within $180 + \epsilon \pm 1''$ has been attained as will be seen by the following table. That precision fully equal to that of the principal

Stations.	Observed angles.	Spherical excess.	Plane angles.	Sum.	Error.
Bowesville..........	43° 18′ 54″·42	0″·41	54″·01	....	....
King Mountain........	79 14 47 ·36	−0 ·41	46 ·95	....	....
Carp	57 26 18 ·96	−0 ·41	18 ·55	59″·51	0″·49
Bowesville..........	48° 25′ 00″·52	-0″·75	59″·77	....	....
Montague	47 30 57 ·00	-0 ·75	56 ·25	....	....
North Mountain	84 04 03 ·92	−0 ·75	03 ·17	59″·19	0″·81
Bowesville..........	30° 31′ 48″·89	-0″·36	48″·53	....	....
North Mountain	71 05 28 ·88	-0 ·36	28 ·52	....	....
Ormond..........	78 22 43 ·43	-0 ·36	43 ·07	00″·12	0″·12
Bowesville..........	74° 29′ 29″·25	-0″·55	28″·70	....	....
Navan.....	59 41 56 ·67	-0 ·55	56 ·12	....	.....
Ormond..	45 48 31 ·87	-0 ·55	34 ·32	59″·14	0″·86

geodetic surveys has been achieved is very encouraging, especially in view of the fact that the opinion has been often expressed, sometimes with assumption of authority, that Canadians, from want of experience, could not cope with the work, and that it would be necessary for the proper carrying on of a geodetic survey in Canada to resort to other countries for instructions in methods and even for the personnel of the survey. All the observers now on the staff are graduates of Canadian universities.

GENERAL REMARKS.

It was confidently expected that the experience of other countries would place geodetic operations beyond the experimental stage. As far as the perfection of angular instruments is concerned, those expectations have been realized. The angles of the triangles tabulated were measured with a twelve-inch, two-microscope, Troughton & Simms theodolite reading directly to seconds of arc, designed for the Great Trigonometrical Survey of India. Unfortunately, for the progress of our work, the adoption of apparatus for signalling—reported highly satisfactory in other countries -proved disastrous; it was found to be wholly inadequate to cope with the atmospheric conditions prevalent in eastern Canada. The Geodetic Survey of Canada has been undertaken for practical purposes, viz.: the establishment of geographic positions for mapping, and for the present is confined to the older and more thickly populated sections, without any regard to their suitability for primary triangulation. Much of this work in other countries is carried on solely for the purpose of adding to their scientific knowledge and the localities for measuring arcs of meridians and parallels of latitude are chosen after duly considering the physical and atmospheric conditions to be encountered.

Although for the present the public utility of the work is dominant, it is hoped confidently that our survey may eventually be used to add to the knowledge of the 'figure and size of the earth' and that in this respect the scientific work of Canada may not remain behind that of other countries.

DESCRIPTION OF METHODS ADOPTED.

The triangulation, by means of which a geodetic survey is spread over a country, is expanded through three, four, five and even six sided figures—from a base line the length of which is carried through the figures by means of the triangles into which they are subdivided. The computation consists of an equal distribution of station errors and an apportionment of the remaining errors of closure of the triangles by means of an elaborate least square adjustment having for its object the determination of the most probable values of the measured angles. In this connection the following extract from 'Instructions' issued to observers is of interest.

EXTRACTS FROM INSTRUCTIONS ISSUED TO OBSERVERS.

'The most important geodetic observations are those determining the angles between the lines radiating from the station occupied. The skill, patience and constantly watchful care of an observer entrusted with this portion of the work count for their full value. Office computations of the most refined and exhaustive nature can only make the best possible use of the material in the records of observations sent in from the field; they cannot in any way compensate unskillful or indifferent observations, as errors introduced in this way are to a large extent local, especially when the observations are made under unfavourable local atmospheric conditions.'

The unfavourable atmospheric conditions referred to above are also dealt with in 'Instructions to Observers' as follows:—

'Observations in connection with primary triangulation for determining geographic positions must not be made when unfavourable atmospheric conditions exist. When the tests outlined by these instructions show that they may be made with confidence, observers and their assistants are expected to continue their work to the limit of physical endurance, that is, to that stage when personal equation becomes a variable. A pencil of light many miles in length near the surface of the earth is subjected to local atmospheric influences which will cause deflections uncertain in magnitude and direction, and, owing to the diversity of conditions along the lines of sight radiating from a trigonometrical station, the amount and trend of these local disturbances are impossible to estimate. A careful study of the physical

features along the lines of sight will enable the observer to reach fairly accurate conclusions as to where such deflections may be expected. The pencil of light in its passage from a distant heliotrope or lamp to the observer's telescope encounters atmosphere varying in temperature and density governed by adjacent hills, masses of timber or low-lying cultivated levels. When the line of sight is from hilltop to hilltop high above the intervening country, the conditions are most favourable, but if a hill rises on one side of the line, lateral displacement must be expected especially if wind is blowing from the hill across the line. When there is wind blowing towards the hill, pointings may be made with confidence.'

'Day observations of primary directions are not desirable, but during the autumn months they may be made when conditions appear favourable. For your guidance in this respect and as a criterion at all times, you are instructed to proceed as follows:—

'Direct your telescope to a distant heliotrope or lamp—preferably along the most unfavourable line—and observe carefully for not less than ten minutes, the action of the image. If the vibration is rapid and uncertain as to direction, but symmetrical in magnitude and covering a small area, careful bisections of this area may be made with confidence, but if you observe the image move slowly to one side and return with similar deliberation—even though the movement may appear uniform—your pointings would be of no value for primary work.'

Instructions embodying the principles governing the Geodetic Survey of Canada are in the hands of all observers. They are the measure of the standard of accuracy adopted, and their preparation has been influenced by a desire that the work should be as distinctly Canadian as possible. Extracts from these instructions are used for purposes of illustration, and also for the better understanding of this report.

DESCRIPTION OF METHODS ADOPTED—RESUMED.

Returning to the description of the form of the triangulation, the figures are so arranged that the computations of the sides may be made through at least two series of triangles. This is accomplished by central stations in the triangles as well as the five and six sided figures. The diagonals of the quadrilaterals forming two triangles upon the same base are observed. The strength of the figures is measured by the relationship between the angles opposite the given and required sides of the triangles composing them.

Assuming the probable error of an angle to be one second of arc, the uncertainty in length caused by that error, as indicated in the sixth decimal place of the logarithmic sines of the angles used in the computation, may be conveniently tabulated for use in the field. In Canada we have secured the best possible figures on the ground to be covered, always having in view the public utility of the survey, as measured by the number of geographical positions determined. The physical features of Canada are not suitable for the formation of geodetic figures upon rigid mathematical principles, but up to the present no difficulty has been experienced, probably owing to the thoroughness of the reconnaissance survey.

The field parties employed during the season of 1907 were as follows:—

One signal building party, consisting of a foreman, assistant foreman and five men to build signal towers.

One observing party, consisting of one observer, one recorder, one cook and eight light-keepers, to observe the angles of the triangles.

Two levelling parties, of one observer, one cook and four men each.

In addition to the above, two assistants were employed on reconnaissance for the purpose of extending the triangulation southwesterly towards Toronto.

SIGNAL TOWERS.

The erection of the high towers at the angular points to overcome the timber is most tedious and laborious. The plan adopted for these structures is a modification of one designed by Sergeant Beaton, of the Royal Engineers of England (see Col. Clarke's Geodesy, page 181). The towers of the present day are of much smaller timber, but owing to the stress introduced and the general form of construction, are more rigid than the older and more expensive structures. They consist of a tripod upon which the theodolite is mounted and a scaffold insulating the observer's weight from the instrument.

The main objections to high tripods are their unsteadiness in wind and liability to torsion caused by unequal heating of the members during the day, followed by cooling at night. The former has been largely overcome by use of sway braces to stop vibration set up by the diagonals, and the latter by using dry timber throughout, the lumber being cut and stored at a central point a year ahead of the construction party.

The building party of 1907 made good progress and at the end of that summer all the towers between a line joining Covey Hill and Montreal—to the east—and Pakenham and Edwardsburgh to the west, (see map accompanying this report)—were completed. Six towers were also built for the purpose of extending the United States Lake Survey from Lake Erie across the Niagara escarpment and Lake Ontario to Toronto, for the purpose of establishing geographical positions for maps under preparation by the Department of Militia and Defence.

The manner of erecting these towers is fully illustrated by plates from photographs taken at the different stages. This system is used for towers as high as eighty-seven feet. The sections above that height are raised from the ground by block and tackle. The highest tower erected to date is one hundred and two feet from the ground to the lamp stand. Towers of this height are at Maxville, Westport, Binbrook and Grand River. The largest timber in their bottom sections is seven by seven—the central sections six by six and the top sections five by five inches. They are apparently as rigid as the lower towers and perfectly satisfactory in every way. Nothing larger than six by six inches is used in the towers eighty-seven feet high. The following is a table of the number of feet, board measure, in the different heights of towers:—

	Feet B.M.
102-foot tower	6,200
87 "	4,600
77 "	4,200
67 "	3,300
47 "	2,200

THE OBSERVING PARTY.

During the season of 1907 a twelve-inch Troughton & Simms theodolite with two micrometers reading to single seconds was used for measuring the angles (see plates 8 and 9), and what is known as the direction method was adopted. The routine is as follows: The most prominent station visible from the observer's tower is chosen to be used as an initial. The telescope is pointed on this station and then on all the other stations in rotation around the horizon clockwise, until the station preceding the initial is reached. The instrument is reversed upon this station and pointings made in the reverse order back to the initial. The micrometers are read forward and backward in conjunction with each pointing. Assuming that twisting—or torsion—of the high tripods is regular and the pointings made at equal intervals of time, the mean of the pointings will be free from any error from this source.

A determination of the angles at a station consists of sixteen pairs of pointings upon each signal. The zero on the azimuth circle for the pointings upon the initial is moved eleven degrees or thereabouts at the beginning of each set. The pointings

in the day time are made upon heliotropes, and at night upon eight-inch acetylene reflectors in charge of men trained for that purpose. The observer instructs the light-keepers by means of the Morse alphabet and a pre-arranged code of signals.

The determination of the direction of each line involves thirty-two telescope, and one hundred and twenty-eight micrometer pointings. Special precautions have been taken to avoid errors in the micrometer pointings caused by imperfect filling of the graduations. In this connection the following is an extract from the 'Instructions to Observers':

'The illumination of the graduations on the azimuth circle must be sufficient to counteract side reflections. You are directed to use artificial light at all times and to arrange the reflector so that the electric hand lamp may be held parallel to the graduations and the light reflected therein so as to illuminate both its edges equally. The reflectors are to be adjusted in position before commencing work and must not on any account be moved, during the progress of an evening's pointings.'

Owing to the prevalence of high timber on the ridges in Ontario, the lines of sight invariably pass close to the tree tops, so that the atmospheric conditions are extremely unfavourable for geodetic work.

PRECISE LEVELS.

Two precise level parties were employed during 1907. The lines levelled followed the main line of the Canadian Pacific Railway from Sherbrooke to St. Johns, with branch lines along the Grand Trunk Railway from Lennoxville and St. Johns; on the Canadian Pacific Railway from Foster, and the Central Vermont Railway from Farnham; south to the international boundary, and also along the Grand Trunk Railway from Lacolle Junction to Coteau Junction. The methods adopted are similar to those of the United States Coast and Geodetic Survey, and are without any special features of interest. The permanent bench marks are copper bolts in the masonry of the culverts and bridges of the railway. They will be described in our next report, which will contain the results obtained during 1907 and 1908. The progress of the work has been hampered by the insufficiency of the optical parts of the instruments in use, necessitating short sights in order to obtain perfect definition. The limit of error allowed is $0^{f}\cdot017\ \sqrt{M}$, 'M' being the distance in miles. New instruments have been ordered from Messrs. Cooke & Sons, York, England. Much delay in their manufacture has been caused by the specification requiring the use of an alloy of thirty-six parts nickel and sixty-four parts iron for the telescope tubes and base castings and an alloy of like proportions of nickel and steel (called Invar) for the more important parts such as level tubes and mounts, the telescope draw tubes and the diaphragms carrying the reticules and their adjusting screws. The new instruments will be in use shortly and owing to the increased optical efficiency more rapid progress will be made, since speed in levelling is regulated largely by the length of the sights.

During the winter of 1907 and 1908 reconnaissance surveys were carried on in western Ontario, central Ontario and in the province of Quebec. A progress map is submitted showing the work accomplished to date. The solid lines join the towers which have been occupied by the observing parties, the dash and dot lines, the towers built but not occupied, and the dotted lines the points selected for towers to be built this season. These latter points are, of course, subject to revision as the work progresses.

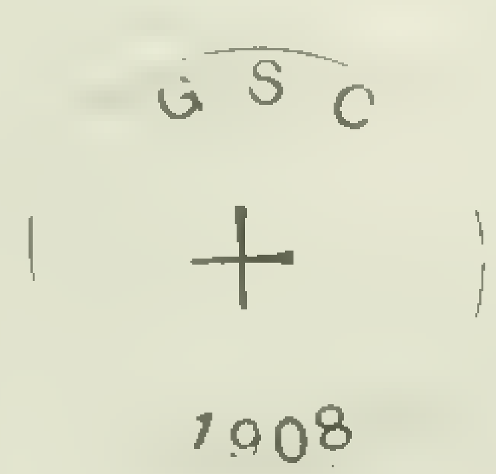
A much more comprehensive and extensive scale of operations has been inaugurated for the present season of 1908. Two observing parties are in the field extending the observations both east and west; an examination of the map will show the work accomplished to date—indicated by the solid lines. This season has been extremely unfavourable for observing. The prevailing low barometer allows the smoke of the cities to spread out over the surface, effectually preventing the use of instruments on the longer lines of the triangulation.

The instructions for 1908 require the observers to close the circle, that is, to reverse on the initial station instead of on the next preceding one. This enables them to form a more accurate estimate of their work as they proceed. It also discloses any twisting of the tripods. As far as the results up to the present are concerned there is no indication of torsion, the closing of the circle upon the initial seldom being more than two-tenths of a second more or less than 360°.

The permanent station marks in earth are as follows: An underground mark consisting of a six-inch glazed sewer tile, twenty-four inches long, on end, flange down, in an excavation two feet square and six feet deep is placed under the instrument point. This pipe and the surrounding space is filled with concrete up to the top of the pipe and a copper bolt six inches long and three-sixteenths of an inch in diameter, dull pointed at top, placed therein, centered under the instrument point. Over this and separated from it by a layer of sand, six inches thick, a surface mark of the same nature is imbedded in earth instead of concrete. The top of this latter mark is eighteen inches below the surface. In addition to the underground marks an artificial stone monument is erected, usually upon the nearest limit between township lots. Upon the base of this monument a copper plate will be placed showing the latitude and longitude of the monument. The azimuth and distance from the station mark to the monument will be published as part of the description of the station.

On mountain tops, or where solid rock occurs, the geodetic point is marked by a round copper bolt, three-quarters of an inch in diameter, 'fox-wedged' and leaded in the rock, surrounded by an equilateral triangle with eight-inch sides, cut with a chisel.

The top of the bolt is stamped with the official die of the Geodetic Survey of Canada as follows:—



Three other copper bolts the same size, at the points of arrows indicating by their direction the central point are placed around the station as reference marks.

Signal building is also progressing more rapidly this season. Two parties (in all eleven men) are at work in central Ontario making rapid and satisfactory progress, and it is confidently expected that all the towers included in the triangulation outlined on the map herewith will be completed by the 15th November. A small party of three men are preparing the stations east of the line joining Montreal and Covey Hill. Their work at the primary stations consists of placing the copper bolts, building lamp stands and preparing three concrete foot blocks for the legs of the tripod of the twelve-inch instrument to rest upon. At some of the stations it may be necessary to build towers. One of the party has been trained in that branch of the work, and with the aid of two additional men, hired temporarily, they can build a tower any height required. The officer in charge of the party in the mountainous districts has been instructed to avoid tower building as much as possible, as it is more economical to clear away the timber.

In addition to the preparation of the primary stations this party is putting in a number of secondary stations at points previously occupied by officials of the Department of Militia and Defence. Their connection with the primary stations, as well as their usefulness for defining the positions of church spires, factory chimneys or other prominent objects of a semi-permanent nature are deemed of importance. No towers are built over secondary stations, and the ordinary tripod signal for day observing is erected instead of a lamp stand for night work. This party is also entrusted with revision of reconnaissance.

PRECISE LEVELS—RESUMED.

During 1908 two levelling parties are in the field, one extending the levels from Sherbrooke along the line of the Canadian Pacific Railway to the international boundary, and the other along the Grand Trunk from Coteau to St. Polycarpe Junction thence along the Canadian Pacific Railway via Kemptville Junction to Prescott, thence westerly along the main line of the Grand Trank Railway. They are making good progress but their efficiency will be much greater when they are supplied with the new English levels referred to. We are indebted to the Boston and Maine, Grand Trunk and Canadian Pacific Railways for permission to use hand-cars on their roads.

BASE LINES.

A base line has been selected at Coteau Junction. It follows the centre line of the right-of-way of the Grand Trunk Railway's main line. Its length is about eight miles and its northeasterly extremity is about two miles east of Coteau Junction and the southwesterly terminus, a short distance west of River Beaudette station. The measurement of the base has been deferred until the completion of the standardizing building at the observatory, in order that the iced bar apparatus may be used therein. Invar tape lines fifty metres long will be used for the field work, and their length referred to a comparator measured by the iced bar apparatus in the standardizing building. 'Invar,' the new alloy of sixty-four parts of steel and thirty-six parts of nickel, is a great boon to geodetic work. Its temperature coefficient is so small that it may be used without the uncertainty of results due to the difficulty of ascertaining the mean temperature of the sections of a long ribbon of steel. Base lines from which geodetic triangulations are expanded, are now, owing to the increased facilities for their measurements, introduced at more frequent intervals, preferably at the junction of comparatively weak figures with those of great strength. For the purpose of our work in Canada it is considered better practice to select the sites for the base lines after the observing towers for the main figures are built, so that the expansion may be as direct and perfect as can be secured throughout the system. The absolute length of a base line is, in the opinion of the writer, of minor importance when compared with the strength of the geometrical figures through which this measurement is carried and with the determination of their angles; an error in the length of a base line produces no distortion. Every possible precaution is exercised in the field and the 'Instructions to Observers' are intended to be exhaustive in this respect. As the measurement of angles progresses, the positions of church spires, brick factory chimneys or other structures of a semi-permanent nature are determined with sufficient precision for geographical purposes. Zenith distances are measured to the tops of towers in order that their relative elevations may be known. Precise level lines will be connected with the towers at convenient points in order that with the aid of the zenith distances measured, the height of the geodetic stations above the level of the sea may be computed.

In conclusion, I desire to acknowledge the zeal and faithfulness of my staff of assistants. Those who have been entrusted with the control of the different branches of the survey have displayed an amount of pride in their work, certain to secure the very best results. The Geodetic Survey of Canada is in every sense a national undertaking, and it is our aim to make the work a credit to our country.

I have the honour to be, sir,
Your obedient servant,

C. A. BIGGER.

25a—31

FIG. 1—Signal on King Mountain.

Fig. 2—Observing Tower, eighty-seven feet high, near Bowesville.

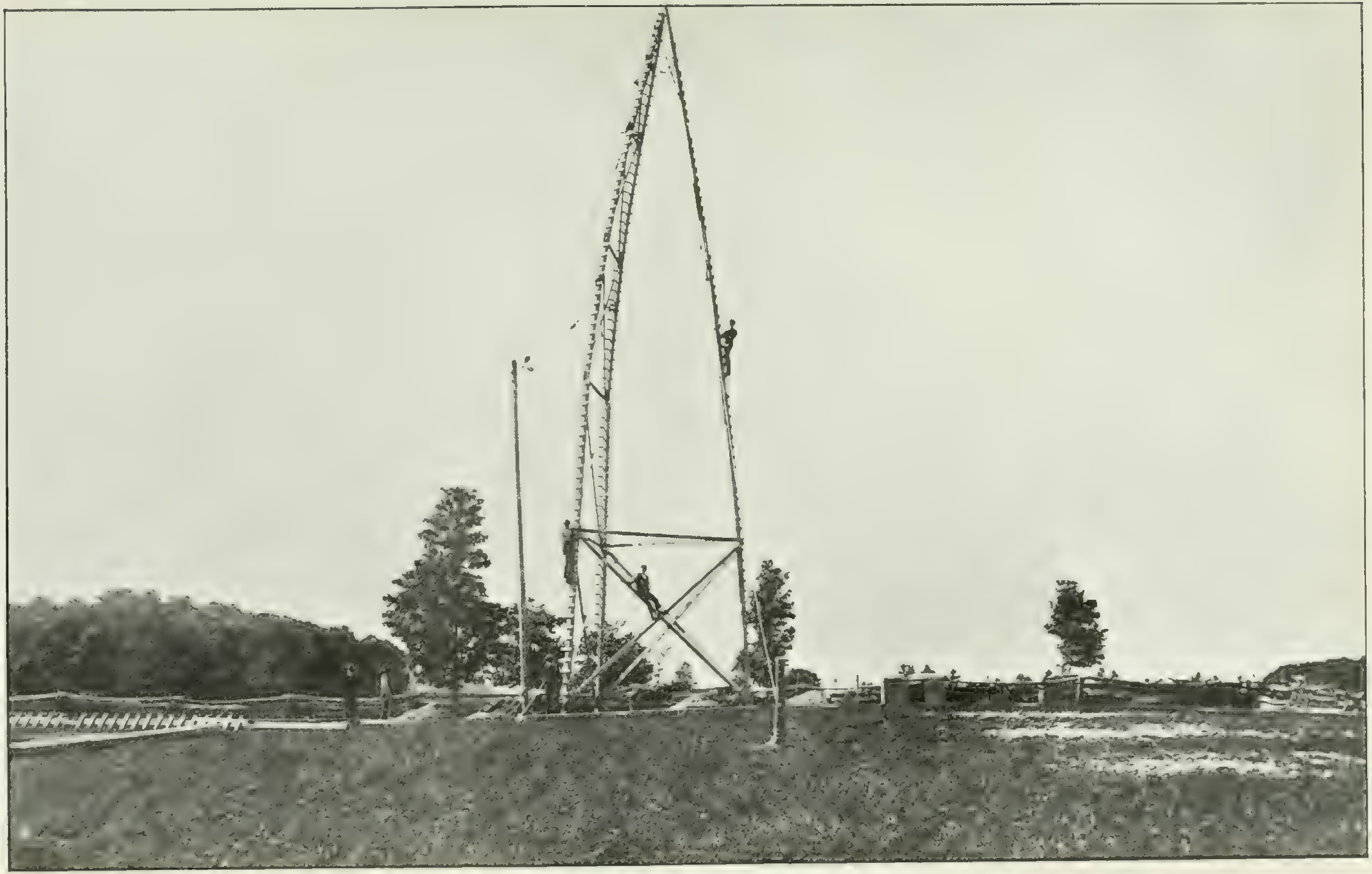


FIG. 3—Manner of erecting eighty-foot tripods.

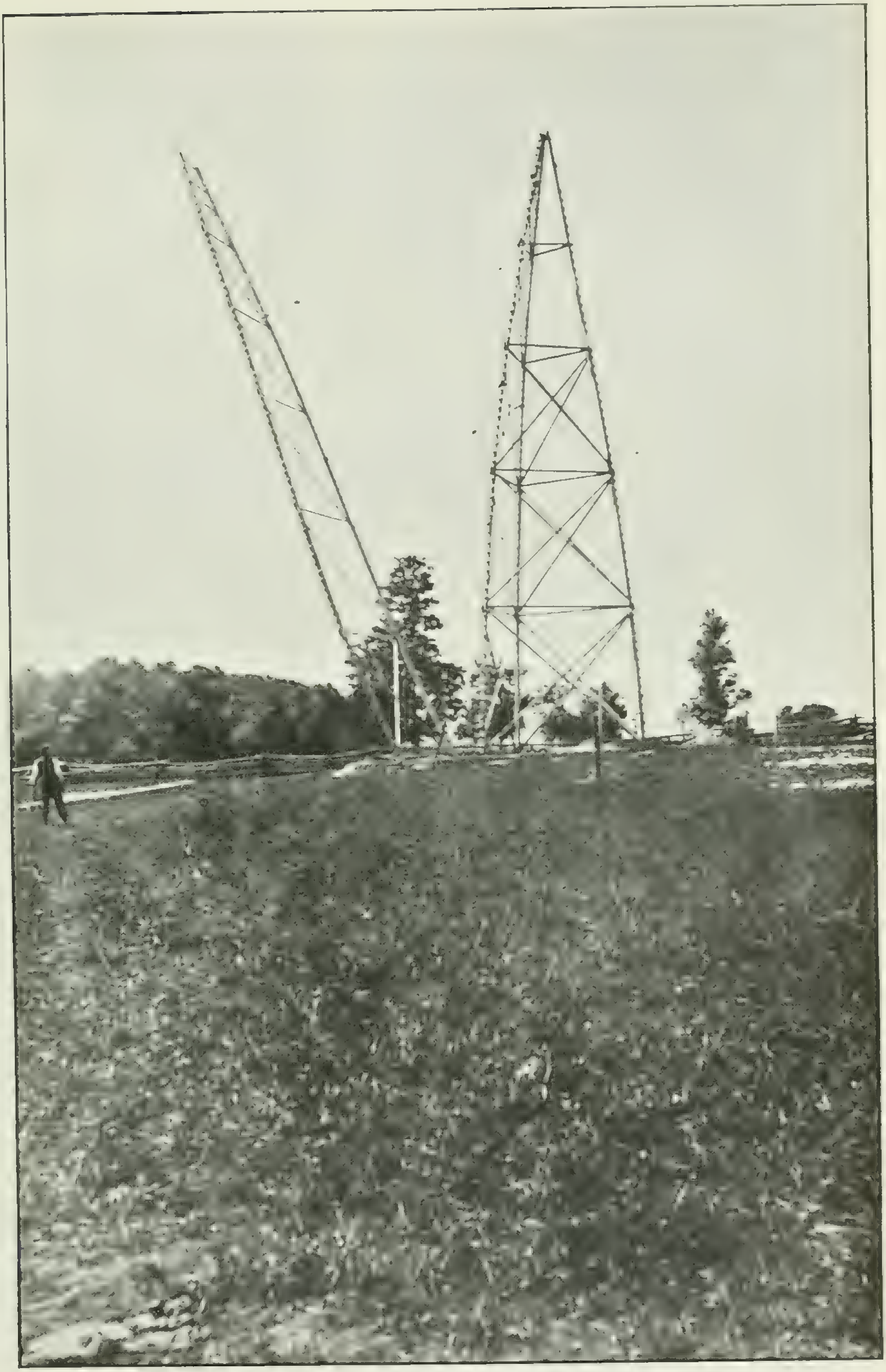


FIG. 4—Using tripod as a derrick to raise first side of scaffold.

FIG. 5—Turning side of scaffold on the ground before raising.

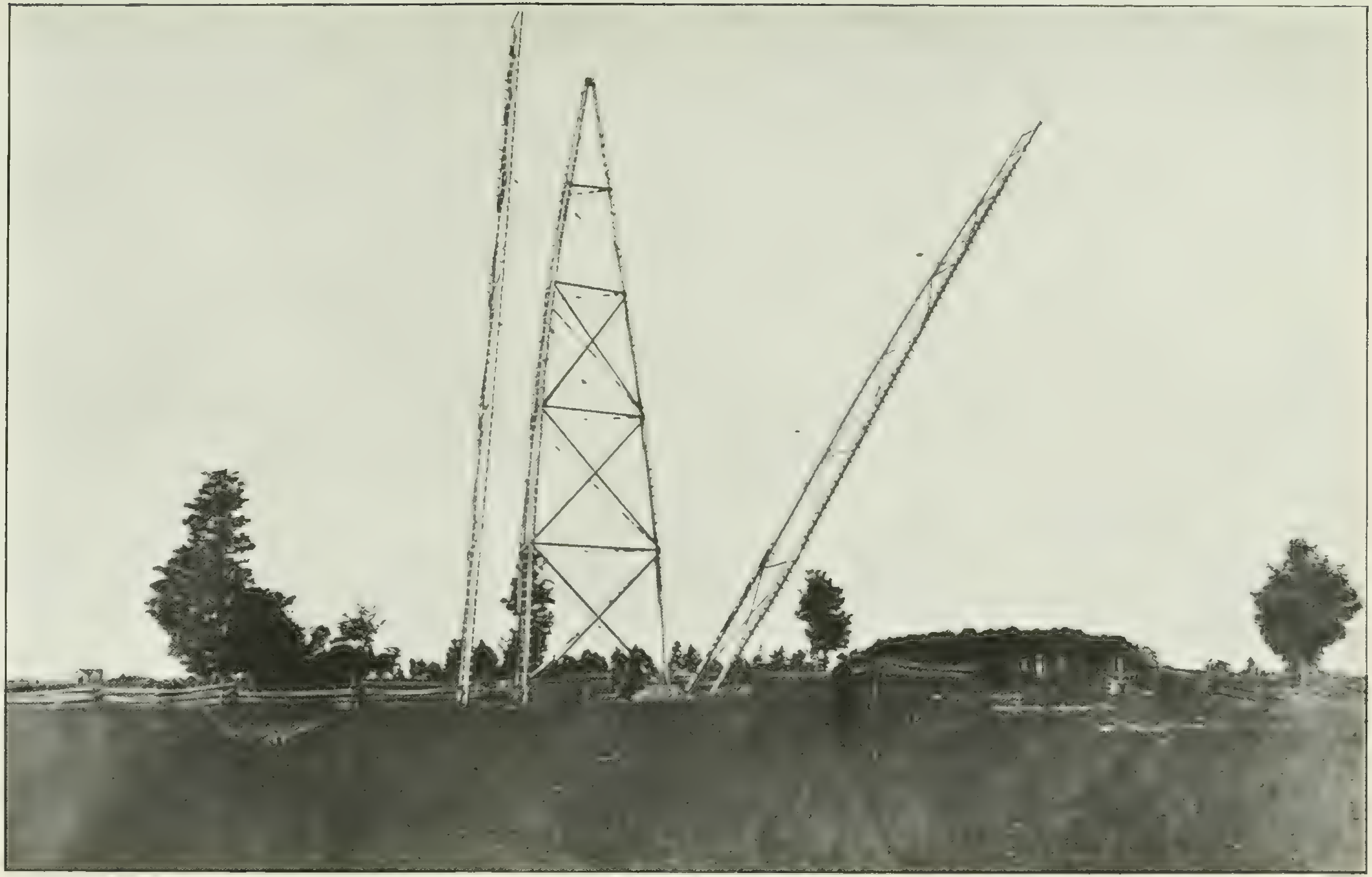


Fig. 6—Raising second side of scaffold.

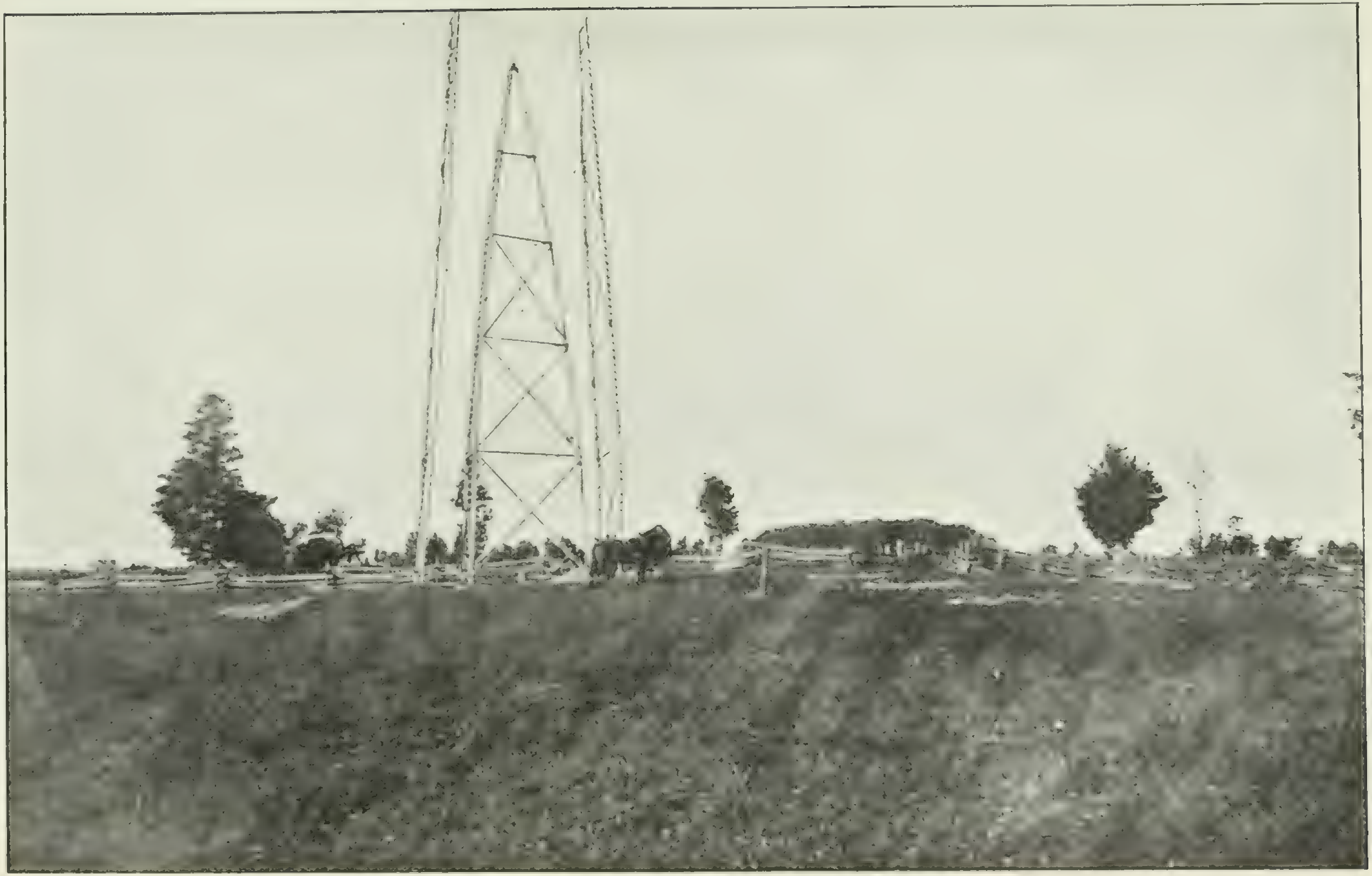


FIG. 7—Both sides of scaffold in place ready for spiking on ties and diagonals, to complete the tower.

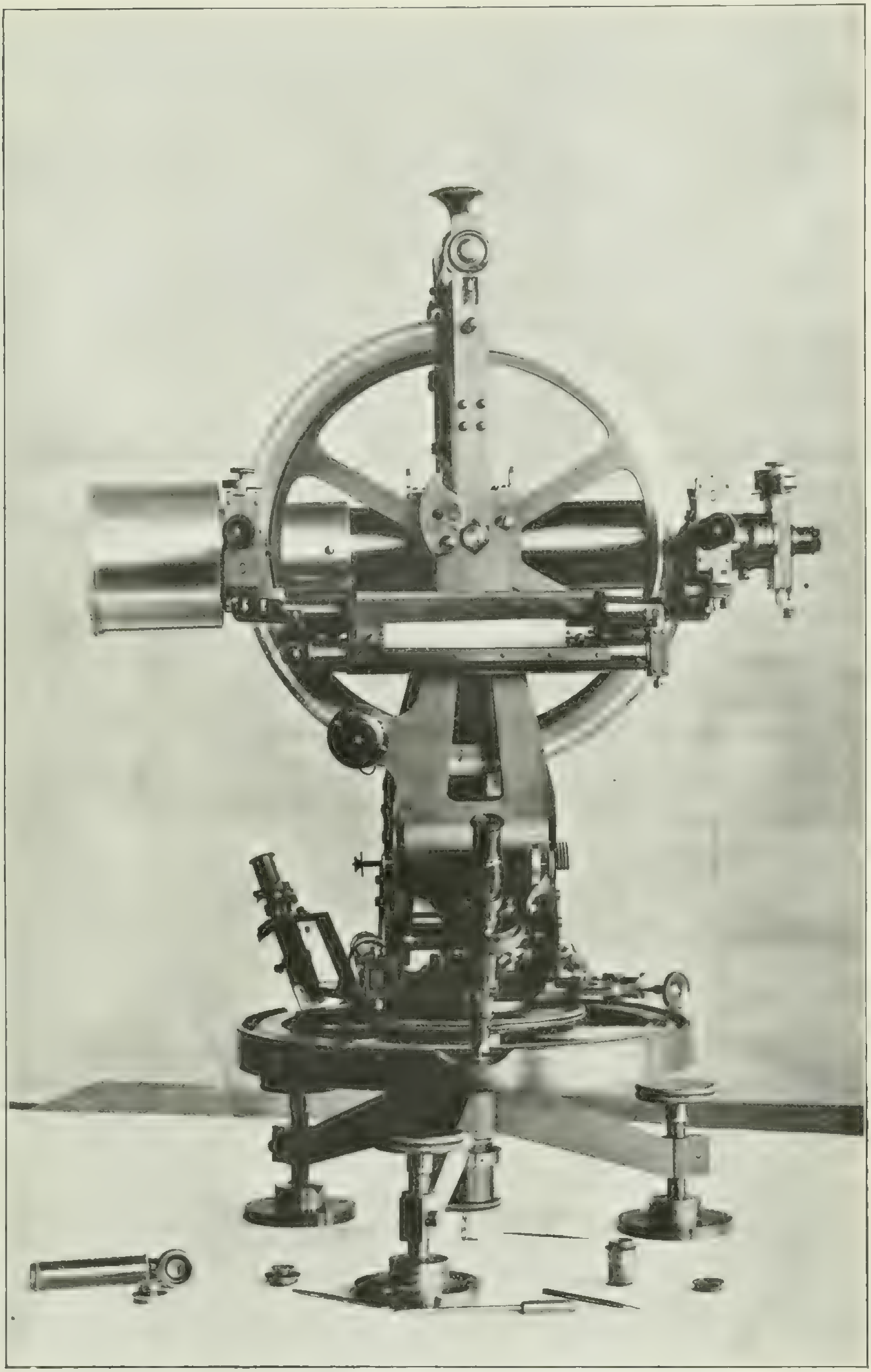


FIG. 8.—Side view of 12-inch Alt-azimuth Theodolite used for measuring horizontal and vertical angles.

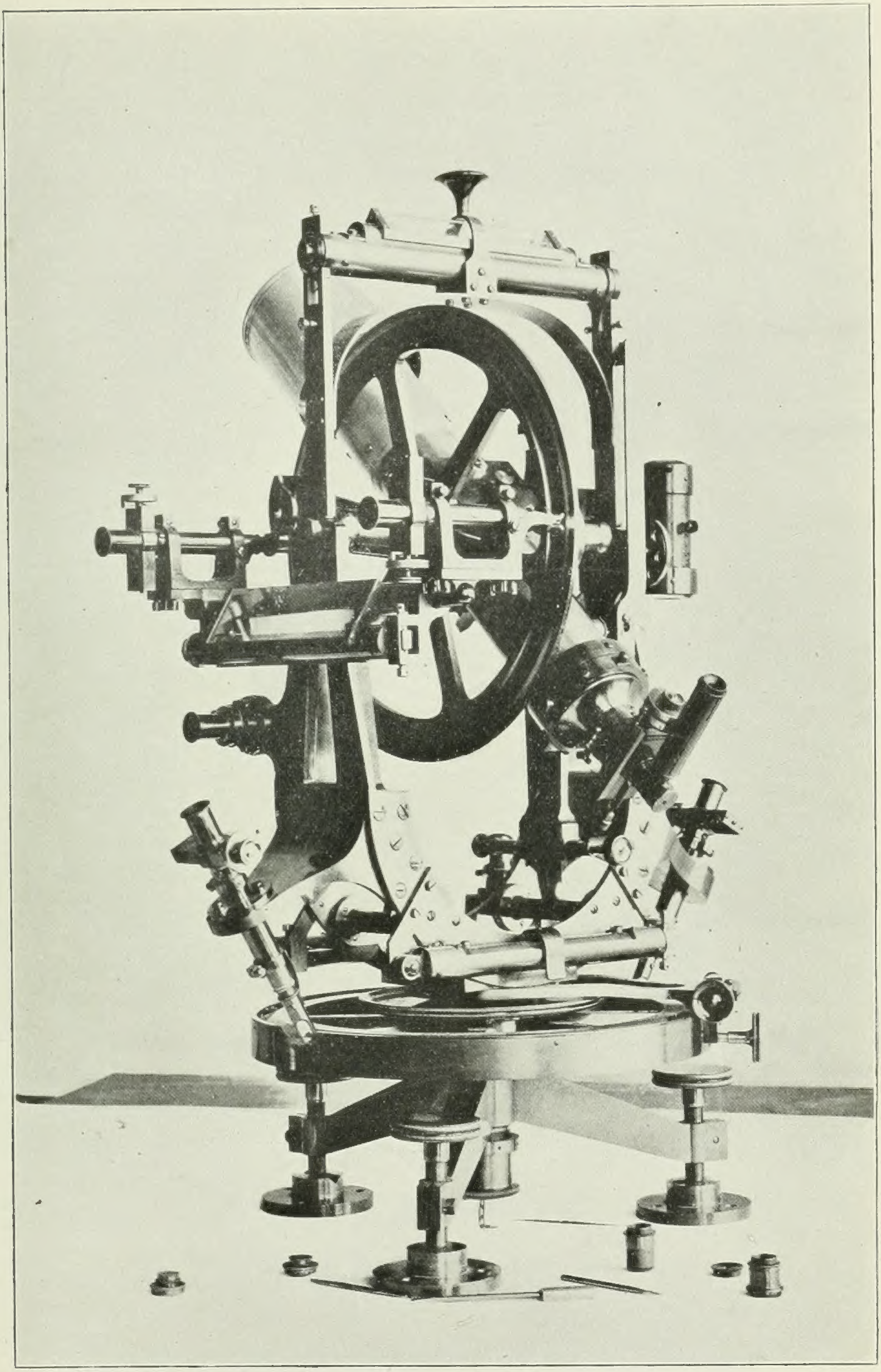


FIG. 9.—Half side view showing attachments of 12-inch Alt-azimuth Theodolite.